Design Guide for Community Water Systems

Effective August 29, 2003

Missouri Department of Natural Resources
Public Drinking Water Program
P.O. Box 176
Jefferson City, MO 65102-0176

Printed on Recycled Paper

PUB000417

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TABLE OF CONTENTS

DEFINITION OF TERMS i
GLOSSARY iii
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PREAMBLE v

CHAPTER 1 -- SUBMISSION OF PLANS 1

1.0 GENERAL 1
1.1 ENGINEERING REPORT 1
1.1.1. General information 1
1.1.2. Extent of the water system(s) 1
1.1.3. Alternate plans 3
1.1.4. Soil, ground water conditions, and foundation problems 3
1.1.5. Flow requirements 3
1.1.6. Sources of water supply 3
1.1.6.1. Surface water sources 3
1.1.6.2. Ground water sources 4
1.1.7. New Technology 5
1.1.7.1. Engineering Report--Additional Requirements for New Technology 5
1.1.7.2. Financial Certification. 6
1.1.7.3. Performance Contract. 7
1.1.7.4. Performance Period. 9
1.1.7.5. (no title) 9
1.1.7.6. (no title) 9
1.1.8. Project Sites. 9
1.2. PLANS 9
1.2.1. Plans shall include: 10
1.2.2. Detailed plans, including: 10
1.3. SPECIFICATIONS. 11
1.4. SUMMARY OF DESIGN CRITERIA. 12
1.5. ADDITIONAL INFORMATION. 12
1.6. REVISIONS TO APPROVED PLANS 12
1.7. FINAL APPROVAL OF CONSTRUCTION. 12
1.8. SUPERVISED PROGRAM. 13

CHAPTER 2 - GENERAL DESIGN CONSIDERATIONS 15

2.0. GENERAL. 15
2.1. DESIGN BASIS 15
2.2. PLANT LAYOUT. 15
2.3. BUILDING LAYOUT. 15
2.4. SITING REQUIREMENTS. 15
2.5 SECURITY MEASURES 16
2.6. ELECTRICAL CONTROLS. 17
2.7. STANDBY POWER. 17
2.8. LABORATORY EQUIPMENT. 17
2.8.1. Testing equipment. 17
2.8.2. Physical facilities. 18
2.9. MONITORING AND RECORDING EQUIPMENT. 18
2.10. PLANT SAMPLE TAPS. 18
2.11. FACILITY WATER SUPPLY 18
2.12. WALL CASTINGS 19
2.13. METERS. 19
2.14. PIPING COLOR CODE 19
2.15. DISINFECTION. 20
2.16. MANUALS AND PARTS LIST. 20
2.17. OTHER CONSIDERATIONS. 20

2.18. AUTOMATION. 20

CHAPTER 3 - SOURCE DEVELOPMENT 23

3.0. GENERAL. 23
3.1. SURFACE WATER 23
3.1.1. Quantity. *23*
3.1.1.1. Reservoir Storage Volume. 23
3.1.1.2. Reservoir Capacity. 23
3.1.1.3. River or Stream as the Sole Source of Water. 24
3.1.1.4. Supplemental Pumping. 24
3.1.2. Quality. *25*
3.1.3. Structures. *25*
3.1.3.1. Intake structure design. 25
3.1.3.2. Raw water pumping wells and transmission mains. 26
3.1.3.3. Raw water storage reservoir. 26
3.1.4. Lakes and reservoirs. *27*
3.1.4.1. Site preparation. 27
3.1.4.2. Construction. 27
3.1.4.3. Water supply dams. 27
3.1.4.4. Recreational uses of public water supply lakes. 27
3.2. GROUNDWATER. 28
3.2.1. Quantity. *28*
3.2.1.1. Minimum capacity. 28
3.2.1.2. Number of sources. 28
3.2.1.3. Auxiliary power. 29
3.2.2. Quality *29*
3.2.2.1. Microbiological quality. 29
3.2.2.2. Physical and chemical quality. 30
3.2.2.3. Radiological quality. 30
3.2.3. Location. *30*
3.2.3.1. Well location. 30
3.2.3.2. Isolation standards. 31
3.2.3.3. Other site location and security considerations. 32
3.2.4. Testing and records. *32*
3.2.4.1. Yield and drawdown tests. 32
3.2.4.2. Geological data. 35
3.2.5. General well construction. *35*
3.2.5.1. Minimum protected depths. 35
3.2.5.2. Special conditions for wells drilled into consolidated formations. 35
3.2.5.3. Special conditions for wells drilled into unconsolidated formations. 36
3.2.5.4. Drilling fluids and additives. 36
3.2.5.5. Surface steel casing. 36
3.2.5.6. Permanent steel casing pipe. 36
3.2.5.7. Gravel pack material. 36
3.2.5.8. Packers. 37
3.2.5.9. Screens. 37
3.2.5.10. Plumbness and alignment requirements. 38
3.2.5.11. Grouting requirements. 38
3.2.5.12. Upper terminal well construction. 40
3.2.5.13. Development. 40
3.2.5.14. Capping requirements. 41
3.2.5.15. Well plugging. 41
3.2.6. Well pumps, discharge piping and appurtenances. *41*
3.2.6.1. Line shaft pumps. 41
3.2.6.2. Submersible pumps 42
3.2.6.3. Discharge piping. 42
3.2.6.4. Pitless well units. 43
3.2.6.5. Casing vent. 43
3.2.6.6. Water level measurement. 44
3.2.6.7. Observation wells. 44

CHAPTER 4 -- TREATMENT **47**

4.0. GENERAL. 47
4.1. CLARIFICATION. 47
4.1.1. Presedimentation, or raw water storage basins. *47*
4.1.2. Rapid Mix. *48*
4.1.3. Flocculation. *48*
4.1.4. Sedimentation. *49*
4.1.5. Solids Contact Unit. *51*
4.1.5.1. Installation. 51
4.1.5.2. Operation. 51
4.1.5.3. Chemical feed. 52
4.1.5.4. Rapid mixing. 52
4.1.5.5. Flocculation. 52
4.1.5.6. Residuals concentrators. 52
4.1.5.7. Residuals removal. 52
4.1.5.8. Cross-connections. 53
4.1.5.9. Detention period. 53
4.1.5.10. Suspended slurry concentrate. 53
4.1.5.11. Water losses. 53
4.1.5.12. Weirs or orifices. 54
4.1.5.13. Upflow rates. 54
4.1.6. Tube or plate settlers. *54*
4.1.6.1. General Criteria. 54
4.2. FILTRATION. 55
4.2.1. Rapid rate gravity filters. *55*
4.2.1.1. Rate of filtration. 55
4.2.1.2. Number. 55
4.2.1.3. Structural details and hydraulics. 56
4.2.1.4. Washwater troughs. 56
4.2.1.5. Filter material. 57
4.2.1.6. Filter bottoms and strainer systems. 58
4.2.1.7. Surface wash or subsurface wash. 58
4.2.1.8. Air Scouring. 59
4.2.1.9. Appurtenances. 60
4.2.1.10. Backwash. 60
4.2.2. Rapid rate pressure filters. *61*
4.2.2.1. General. 61
4.2.2.2. Rate of filtration. 61
4.2.2.3. Details of design. 61
4.3. MEMBRANE FILTRATION DESIGN. 62
4.3.1. Membrane filtration performance. *62*
4.3.2. Membrane Filtration. *63*
4.3.2.1. Source water testing. 63
4.3.2.2. Seasonal source water variation. 63
4.3.2.3. Water quality extremes. 63
4.3.2.4. Test results. 63
4.3.3. Design Flux. *63*
4.3.4. Design Pressure Drop or Transmembrane Pressure. *64*
4.3.5. Membrane Fouling. *64*
4.3.5.1. System integrity. 64
4.3.5.2. Membrane design. 64
4.3.5.3. Direct testing equipment. 64
4.3.5.4. Membrane backwashing and air filtration. 64
4.3.5.5. Chemical cleaning. 65
4.3.6. Membrane Rating. *65*
4.3.7. Recovery. *65*
4.3.8. Membrane Filtration Design. *65*
4.3.9. Flow Meters. *66*
4.3.10. Post Treatment. *66*

4.3.11. Waste Disposal. *66*
4.4. DISINFECTION..... 66
4.4.1. Contact time and point of application. *66*
4.4.2. Residual disinfectant. *67*
4.4.3 Testing equipment. *68*
4.4.4 Other Disinfecting Agents. *68*
4.4.5. Ozone Disinfectant. *68*
4.4.5.1. Bench scale studies. 68
4.4.5.2. Chief operators. 68
4.4.5.3. Disinfectant residual. 68
4.4.6. Disinfection Byproduct and Precurser Removal and Control *68*
4.4.6.1. Methods of controlling precursors at the source. 69
4.4.6.2. Removal of disinfection byproduct precursors and control of disinfection byproduct formation. 69
4.4.6.3 Removal of disinfection byproducts. 71
4.4.6.2 Use of alternative disinfectants. 72
4.5. SOFTENING. 73
4.5.1 Lime or lime-soda process. *73*
4.5.2. Cation exchange process. *73*
4.6. AERATION. 76
4.6.1 Forced or induced draft aeration. *76*
4.6.2 Pressure aeration. *76*
4.6.3. Spraying. *77*
4.6.3 Other methods of aeration. *77*
4.6.4 Protection of aerators. *77*
4.6.5 Disinfection. *77*
4.6.6 Bypass. *77*
4.6.7 Corrosion control. *77*
4.7. IRON AND MANGANESE CONTROL 78
4.7.1. Removal by oxidation, detention and filtration. *78*
4.8. CONTROL OF ORGANIC CONTAMINATION..... 80
4.8.1 Engineering Report. *80*
4.8.2 Control Alternatives. *81*
4.9. STABILIZATION..... 82
4.9.1. Carbon dioxide addition. *82*
4.9.2. Acid addition. *82*
4.9.3. Phosphates. *82*
4.9.4. Split Treatment. *83*
4.9.5. Alkali Feed. *83*
4.9.6. Carbon dioxide reduction by aeration. *83*
4.9.7. Other treatment. *83*
4.9.8. Water unstable due to biochemical action in distribution system. *84*
4.9.9. Control. *84*
4.10. TASTE AND ODOR CONTROL. 84
4.10.1 Flexibility *84*
4.10.2. Chlorination. *84*
4.10.3. Chlorine dioxide. *84*
4.10.4. Powdered activated carbon. *85*
4.10.5. Granular activated carbon adsorption units. *85*
4.10.6. Copper sulfate and other copper compounds. *85*
4.10.7. Aeration. *85*
4.10.8. Potassium permanganate. *85*
4.10.9. Ozone. *85*
4.10.10. Other methods. *86*
4.11. Waste Handling and Disposal *86*
4.11.1. Earthen Lagoons and Holding Basins. *87*
4.11.2. Sanitary waste. *87*
4.11.3. Brine waste. *87*

4.11.4. Lime softening residuals *88*
4.11.5. Clarification and Coagulation Residuals *89*
4.11.6. Iron and Manganese Residuals and Wastewater. *90*
4.11.7. Filter Backwash Water *92*
4.11.8. Wastes from Plants using Missouri or Mississippi River Water *93*

CHAPTER 5 -- CHEMICAL APPLICATION 95

5.0 GENERAL. 95
5.0.1. Plans and specifications. *95*
5.0.2. Chemical application. *95*
5.0.3. General equipment design. *96*
5.1. FACILITY DESIGN. 96
5.1.1. Number of feeders. *96*
5.1.2. Control. *96*
5.1.3. Dry chemical feeders. *97*
5.1.4. Positive displacement solution pumps. *98*
5.1.5. Liquid chemical feeders - Siphon control. *98*
5.1.6. Backflow Prevention. *98*
5.1.7. Chemical feed equipment location. *99*
5.1.8. Service water supply. *99*
5.1.9. Storage of chemicals *99*
5.1.10. Solution tanks. *101*
5.1.11. Day tanks. *101*
5.1.12. Chemical Feed lines. *102*
5.1.13. Pumping of Chemicals. *103*
5.1.14. Handling. *103*
5.2. CHEMICALS. 104
5.2.1 Shipping containers. *104*
5.2.2 Assay *104*
5.3. OPERATOR SAFETY. 104
5.3.1 Ventilation. *104*
5.3.2. Respiratory protection equipment. *104*
5.4. SPECIFIC CHEMICALS. 104
5.4.1. Chlorine gas. *104*
5.4.2. Acids. *108*
5.4.3. Chlorine Dioxide. *108*
5.4.4. Chloramines. *109*
5.4.5. Carbon dioxide *111*
5.4.6. Phosphates. *111*
5.4.7. Powdered activated carbon. *111*
5.4.8. Fluoridation *113*
5.5. OZONE 116
5.5.1. Ozone Generator *117*
5.5.2. Ozone Contactors. *117*
5.5.3. Ozone Destruction Unit. *118*
5.5.4. Piping Materials. *119*
5.5.5. Joints and Connections. *119*
5.5.6. Instrumentation. *119*
5.5.7. Alarms. *120*
5.5.8. Safety. *120*
5.5.9. Construction Considerations. *121*
5.6. OZONE FEED GAS PREPARATION 121
5.6.1. Air Compression. *121*
5.6.2. Air Drying. *121*
5.6.3. Air Filters. *122*
5.6.4. Air Preparation Piping. *122*

CHAPTER 6 -- MINIMUM CONSTRUCTION REQUIREMENTS FOR PUMPING FACILITIES 123

6.0 GENERAL 123
6.01. National Standards. *123*
6.02. OTHER GENERAL STANDARDS. 124
6.1. LOCATION. 125
6.2. PUMPING STATIONS. 125
6.2.1. Finished and raw water pumping stations. *125*
6.2.2. Suction wells. *126*
6.2.3. Motor and Pump Installation and Removal. *126*
6.2.4. Stairways/Ladders. *126*
6.2.5. Heating, Ventilation, Lighting, and Dehumidifying. *126*
6.2.6. Dehumidification. *127*
6.2.7. Manned pumping stations. *127*
6.3. PUMPS. 128
6.3.1. 128
6.3.2. 128
6.3.3. Pumping unit design and construction. *128*
6.3.4. Suction Lift. *129*
6.4. ADDITIONAL REQUIREMENTS FOR BOOSTER PUMPS. 129
6.4.1. Booster pumping station *129*
6.4.2. Booster Pumps Drawing from Storage Tanks *129*
6.4.2.1. Booster pumps drawing from storage tanks. 129
6.4.2.2. Suction lines. 130
6.4.3. Inline booster pumps *130*
6.4.4. Individual home booster pumps *130*
6.4.5. Automatic stations *130*
6.5. APPURTENANCES. 130
6.5.1. Valves. *130*
6.5.2. Piping. *130*
6.5.3. Gauges and meters. *131*
6.5.4. Water Seals. *131*
6.5.5. Controls. *131*
6.5.6. Power. *131*
6.5.7. Water pre-lubrication. *132*

CHAPTER 7 -- MINIMUM CONSTRUCTION STANDARDS FOR FINISHED WATER STORAGE TANKS AND RESERVOIRS 133

7.0. GENERAL DESIGN AND CONSTRUCTION STANDARDS 133
7.0.1. AWWA Standards for Unpressurized Tanks and Reserviors *133*
7.0.2. Parameters for Unpressurized Tanks and Reservoirs for Finished Water Storage *133*
7.0.3. Location *134*
7.0.4. Roofs on Unpressurized Finished Water Storage Structures *135*
7.0.5. Protection of Finished Water Storage Structures *135*
7.0.6. Vents on Unpressurized Finished Water Storage Structures *135*
7.0.7. Overflows on Unpressurized Finished Water Storage Structures *135*
7.0.8. Freeze Protection for Unpressurized Finished Water Storage Structures *136*
7.0.9. Catwalks *136*
7.0.10. Corrosion Protection *136*
7.0.11. Drains on Unpressurized Tanks and Reservoirs *137*
7.0.12. Roofs and Sidewalls on Unpressurized Tanks and Reservoirs *137*
7.0.13. Access to Unpressurized Finished Water Storage Structures *138*
7.0.14. Discharge Pipes *138*
7.0.15. Safety Devices at Unpressurized Finished Water Storage Structures *138*
7.0.16. Disinfection of Unpressurized Finished Water Storage Structures *139*
7.1. TANKS AND RESERVOIRS FOR FINISHED WATER STORAGE 139

7.1.1. Fire Protection. ... *139*
7.1.2. No Fire Protection. ... *139*
7.1.3. Tank and Reservoir Capacity for Unpressurized Tanks ... *140*
7.1.3.1. Elevations. ... 140
7.1.3.2. Volumes. ... 141
7.1.4. Costs ... *142*
7.2. PLANT STORAGE ... 142
7.2.1. Filter Backwash. ... *142*
7.2.2. Clear Wells. ... *142*
7.2.3. Receiving Basins and Pump Wet Wells ... *142*
7.2.4. Finished Water Adjacent to Unsafe Water ... *142*
7.3. DISTRIBUTION STORAGE ... 143
7.3.1. Minimum PSIG at Normal Ground Elevation ... *143*
7.3.2. Working Pressure PSIG at Normal Ground Elevation ... *143*
7.3.3. Distribution Storage Controls ... *143*
7.4. HYDROPNEUMATIC STORAGE ... 144
7.4.1. Hydropneumatic storage. ... *144*
7.4.2. Pressure tanks. ... *144*
7.4.3. Boyle's Law. ... *144*
7.4.4 Pressure tanks or bladder tanks used as the only storage for small community water supplies. ... *144*
7.4.5. Pressure/Bladder Tanks Used with Other Storage and Booster Pumps ... *145*
7.4.6. Pressure Tanks -- Separate Inlet and Outlet Lines ... *145*
7.4.7. Bladder Tanks - Individually Connected ... *145*
7.4.8. Certification of Hydropneumatic Tanks ... *145*
7.4.9. Hydropneumatic Tank Design and Construction ... *145*
7.4.10. Pressure Tanks That Provide Disinfection Contact Time ... *145*
7.4.11. Pressure Tanks with Gross Volume of 1,000 Gallons or More ... *145*
7.4.12. Pressure and Bladder Tanks with Gross Volume of less than 1,000 Gallons. ... *146*
7.4.13. Protection to Metal Surfaces ... *146*
7.5. FIRE FLOW INFORMATION ... 147
7.5.1. Standard Fire Flow with Corresponding Fire Durations. ... *147*
7.5.2. Fire Suppression Rating Schedule. ... *148*
7.5.3. Storage for Fire Flow ... *148*

CHAPTER 8 - DISTRIBUTION SYSTEMS ... 149

8.0. MATERIALS. ... 149
8.0.1. Standards and materials selection. ... *149*
8.0.2 Permeation of pipe walls. ... *149*
8.0.3. Used materials ... *149*
8.0.4. Joints. ... *149*
8.1. WATER MAIN DESIGN ... 149
8.1.1. Pressure. ... *149*
8.1.2. Diameter. ... *150*
8.1.3. Fire Protection ... *150*
8.1.4. Flushing. ... *150*
8.2. VALVES. ... 150
8.3. FIRE HYDRANTS. ... 151
8.3.1. Location and spacing. ... *151*
8.3.2. Valves and nozzles. ... *151*
8.3.3. Hydrant leads. ... *151*
8.3.4. Drainage. ... *151*
8.4. AIR RELIEF VALVES; VALVE, METER AND BLOW-OFF CHAMBERS ... 151
8.4.1. Location. ... *151*
8.4.2. Piping. ... *151*
8.4.3. Chamber drainage. ... *151*
8.5. INSTALLATION OF MAINS. ... 152

8.5.1. Standards. *152*
8.5.2. Bedding. *152*
8.5.3. Cover. *152*
8.5.4. Blocking. *152*
8.5.5. Pressure and leakage testing. *152*
8.5.6. Disinfection. *152*
8.6. SEPARATION OF WATER MAINS, SANITARY SEWERS AND COMBINED SEWERS 153
8.6.1. General. *153*
8.6.2. Parallel installation. *153*
8.6.3. Crossings. *153*
8.6.4. Exception. *153*
8.6.5. Force mains. *154*
8.6.6. Sewer manholes. *154*
8.6.7. Disposal facilities. *154*
8.7. SURFACE WATER CROSSINGS. 154
8.7.1. Above-water crossings. *154*
8.7.2. Underwater crossings. *154*
8.8. BACKFLOW PREVENTION 155
8.9. WATER SERVICES AND PLUMBING. 155
8.9.1. Plumbing. *155*
8.9.2. Booster pumps. *155*
8.10. SERVICE METERS 155
8.11. WATER LOADING STATIONS. 155
8.11.1. Backflow. *155*
8.11.2. Filling device. *156*
8.11.3. Hose length. *156*

Tables

Figure 1 - Piping Color Code 19

Figure 2 - New Well Isolation Radii 31

Figure 3 - Steel Pipe 45

Figure 4 - Hydropneumatic Tank Usable Volume 144

Figure 5 - Design Needed Fire Flow 147

Figure 6 - Population and Fire Flow 148

DEFINITION OF TERMS

The following is a list of terms used throughout this document and the definition of each.

Average Day Demand-- The amount of water used in an average day. Calculated by dividing the total annual water production by the number of days in the year.

Comprehensive Performance Evaluation (CPE)-- A systematic review and analysis of a water treatment plant's performance without major capital improvements. It is the first part of a composite correction program.

Continuing Operating Authority -- The permanent organization, entity or person identified on the permit to dispense water who is responsible for the management, operation, replacement, maintenance and modernization of the public water system in compliance with the Missouri safe drinking water statutes and regulations (see definition in 10 CSR 60-3.020).

Design Instantaneous Peak Flow -- The flow rate measured at the instant the maximum demand is occurring in a water system. It is calculated by dividing the cross-sectional area of the water pipe by the velocity of the water at any one instant.

Design Average Day Demand -- The anticipated amount of water used in an average day. Calculated by dividing the anticipated total annual water production by the number of days in the year.

Design Maximum Day's Demand -- The anticipated amount of water needed to satisfy the day of highest water usage. Typically, this is 150% of the Average Day Demand.

Design Period -- The span of time any proposed water system or water system component will be utilized.

Diurnal Flow Pattern -- A plot of water demand versus time for a 24-hour period. The curve depicts a typical period of time and is used to simulate the daily operation of the network, especially the cycling of system storage.

Fire Protection -- The ability to provide water through a distribution system for fighting fires in addition to meeting the normal demands for water usage.

Historical Data -- Actual records of past water production, consumption, and other operational information.

Maximum Day Demand --The amount of water needed to satisfy the day of highest water usage. Typically, this is 150% of the Average Day Demand.

Maximum Flow -- The greatest amount of water demanded within a specified time period.

Maximum Hour Demand -- The amount of water needed to satisfy the highest flow rate in a water system occurring for a one-hour duration.

Peak Demand -- The maximum momentary load, expressed as a rate, placed on a water treatment plant, distribution system, or pumping station. It is usually the maximum average load in one hour or less, but may be specified as instantaneous or for some other short time period.

Peak Flow -- See Maximum flow.

Period of Record -- The time span covered by a particular set of data.

GLOSSARY

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CFR	Code of Federal Regulations
CPE	Comprehensive Performance Evaluation
CSR	Code of State Regulations
FAA	Federal Aviation Administration
GAC	Granular Activated Carbon
ISO	Insurance Services Office
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutants Discharge Elimination System
NSF	National Sanitation Foundation
NSF	National Science Foundation
OSHA	Occupational Safety and Health Administration
PAC	Powdered Activated Carbon
PDWP	Public Drinking Water Program
PPE	Personal Protective Equipment
PSIG	Pounds per square inch gauge
PVC	polyvinylchloride
RSMo	Revised Statutes of Missouri
USC	United States Code
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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PREAMBLE

What is the Purpose of This Document?

This publication reflects the minimum standards and guidelines of the Missouri Department of Natural Resources in regard to the preparation, submission, review, and approval of engineering reports, plans, and facilities for the construction or modification of community water systems. These standards are necessary for facilities to comply with the Missouri safe drinking water statutes and regulations.

These standards, consisting of proven technology, engineering principles, and sound water works practices, are intended to accomplish the following objectives: to serve as a guide for professional engineers in the design and preparation of engineering reports, plans, and specifications for community public water systems; to suggest limiting values for items upon which evaluation of such engineering reports, plans, and specifications are evaluated by the department; and to ensure that a new or modified community public water system facility will be capable of supplying adequate water in compliance with applicable regulations.

These standards draw heavily on the Recommended Standards for Water Works, commonly known as the “Ten State Standards.” The Great Lakes-Upper Mississippi Board of Public Health and Environmental Managers created a Water Supply Committee in 1950 consisting of one associate from each state represented on the Board (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin). In 1978, a representative of the Canadian province of Ontario was added. This committee was assigned the responsibility for reviewing existing water works practices, policies, and procedures, and reporting its findings to the Board. The report of the Water Supply Committee was first published in 1953, and has been updated and revised several times since then. The “Ten State Standards” are widely accepted throughout the water works industry as minimum standards for construction of safe water supplies.

To Whom Do These Standards Apply?

These standards apply to new community water systems. These standards also apply to modifications made at existing community water systems. Only the portion of the existing community water system begin modified is subject to these standards. These standards are not an inspection tool for assessing deficiencies in facilities constructed under approvals issued under previous Design Guides. However, where water quality performance is an issue, appropriate portions of these minimum standards may be applied (for example, in Comprehensive Performance Evaluations).

What Does This Document Require?

Where the terms “shall” and “must” are used, mandatory requirements are indicated. These terms are used where practice is sufficiently standardized to permit specific delineation of requirements or where safeguarding public health justifies such definition action. Other terms, such as “should,” “recommended,” and “preferred,” indicate desirable procedures or methods,

and deviations are subject to individual consideration, but these terms in no way indicate a requirement.

Deviation from the mandatory “shall” or “must” requirements will be considered by the department on a case-by-case basis, based on the primary purpose of the proposed water works, the local conditions governing their functions, and operation.

In many instances in this document, choices and alternatives are provided for meeting a requirement. For example, the engineering report shall include information on usage rates, water loss rates, unusual conditions, and population per service connection. That is the requirement. However, this information can be based on any one of four alternatives: (1) historical data from the water system if available; <u>OR</u> (2) data from a comparable system; <u>OR</u> (3) calculations of usage criteria using data specified in the document; <u>OR</u> (4) some other usage criteria if adequate justification is provided.

This approach provides flexibility in meeting basic requirements that ensure the proposed new or modified water system provides safe quality and adequate quantities of drinking water. This flexibility is provided where appropriate throughout the document.

Approval of the use of “other criteria,” where that option is offered, must, of necessity, be somewhat subjective and situation-specific. However, the department feels it is important to allow this extra degree of flexibility to the water system and its engineers.

What Process Will the Department Use to Evaluate and Accept Alternative Designs?

It is not possible to cover recently developed processes and equipment in a publication of this type. However, it is the policy of the department to encourage rather than obstruct the development of new processes and equipment. Recent developments may be acceptable if they meet at least one of the following conditions:

1. They have been thoroughly tested in full scale comparable installations under competent supervision;
2. They have been thoroughly tested as a pilot plant operated for a sufficient time to indicate satisfactory performance; or
3. A performance bond or other acceptable arrangements have been made so the owners or official custodians are adequately protected financially or in case of failure of the process or equipment.

More specific information and requirements are provided in section 1.1.7.

Regardless of the alternative data presented, the basic criteria for evaluating its merit remains the same: does the alternative criteria offer a comparable level, quantity, and quality of information as the other options offered in the document (usually historical or comparable data or specific calculations), and does the data demonstrate that the alternative design provides equivalent or superior performance under the anticipated extreme operating conditions?

What Process is Available for Appealing the Department's Decision to Reject an Alternative Design?

While the review of most project and construction documents proceeds in a relatively innocuous manner, culminating in an approval being issued, there are times when the PDWP staff engineer and the water system or its consultant may be unable to reconcile a difference. The water system owner/operator may pursue a formal appeal of the department's decision to the Safe Drinking Water Commission, through the authority provided affected parties in section 640.010.1, RSMo; however, the PDWP recommends that the following dispute resolution process be followed prior to resorting to formal procedures:

1. If the PDWP staff engineer determines that the proposed design does not meet regulatory criteria or acceptable engineering practices as established in this document, the PDWP engineer will explain, in writing, the basis for the decision.
2. If the system or its design engineer or consulting engineer disagrees with the PDWP staff engineer's written conclusion, the design or project engineer must submit the basis of their disagreement, in writing, to the PDWP staff engineer.
3. The PDWP staff engineer will share the information submitted by the design or project engineer with management and other professional engineers in the PDWP and solicit their opinions regarding the design or project engineer's response.
4. The PDWP's position on the specific issue will be established by the program director. The PDWP program director's response will be provided to the water system and its engineer(s) within 30 calendar days of the receipt of the system's response identified in item 2, above.

If the water system's owner/operator or consulting engineer remains in disagreement with the department's position, a formal appeal process could be initiated, as applicable, under the authority provided in section 640.010.1, RSMo.

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Chapter 1 -- Submission of Plans

1.0 General

A minimum of two copies of all engineering reports, final plans, and specifications should be submitted at least 30 working days prior to the date on which action by the department is desired. A completed and signed “Application for a Construction Permit” shall be submitted with all detailed plans and specifications. This form can be obtained from the department. Other federal, state, or local agencies may require permits for construction, waste discharges, stream crossings, etc. Preliminary plans and the engineer's report should be submitted for review prior to the preparation of final plans. No approval for construction shall be issued until final, complete, detailed plans and specifications have been submitted to the department and found to be satisfactory. Documents submitted for formal approval shall include but may not be limited to:

a. Applications for a construction permit;
b. A summary of the basis of design, including hydraulic calculations sufficient to demonstrate the system will operate satisfactorily;
c. General layout;
d. Detailed plans;
e. Specifications; and
f. Readily available cost estimates.

1.1 Engineering Report

An engineering report is required for the development of a new water supply system, new water sources, and expansions or modifications to existing water systems that will result in changes to the treatment process and/or overall production capacity. The engineering report shall, where pertinent, present the information listed in this chapter.

1.1.1. General information

General information, including:

a. The name and mailing address of the water system’s continuing operating authority as defined in 10 CSR 60-3.020;
b. A description of the existing and proposed water system(s);
c. A description of the existing and proposed sewerage system and sewage treatment works as it affects the existing or proposed water system;
d. An identification of the municipality(-ies) or area served; and
e. An imprint of professional engineer’s seal or conformance with State of Missouri’s engineering registration requirements.

1.1.2. Extent of the water system(s)

Extent of the water system(s), including the information in items a. through g. below.

a. A description of the nature and extent of the area to be served, including layout maps or drawings showing the legal boundaries of the water system(s).
b. Provisions for extending the water system to include additional areas.
c. Appraisal of the future requirements for service, including existing and potential residential, industrial, commercial, institutional, and other water supply needs.
d. Usage rates, water loss rates, unusual conditions, and population per service connection. This information shall be based on one or more of the alternatives listed in items 1. through 4.
    1. Historical data from the public water system, if available. This data shall be representative of climatic conditions that affect demand and source.
    2. If such historical data from the public water system are not available, data from a comparable water system may be used.
    3. If neither historical nor comparable water system data are available, the following information shall, as a minimum, be used for design purposes:
       i. Population per service connection for permanent residential dwelling units including houses, mobile homes, condominiums, apartments, and multiplexes shall be approximately three (3.0) persons/dwelling unit**;** and
       ii. Domestic water usage for residential dwelling units excluding lawn/garden irrigation usage shall be an average of 80 gallons per person per calendar day, except that for rural water districts this may be an average of 60 gallons per person per day.
    4. Other usage criteria may be used in lieu of the criteria listed in the preceding item (1.1.2.d.3.) if the engineer provides adequate justification.
e. For lawn watering, the following estimates may be used:

Housing Type	Sprinkler Type	Flow per House
Moderate/Middle Class	End of Hose	1.25 gpm
Estate	Automatic	2 gpm

f. Peak flow (instantaneous, one hour, two hour, three hour, or four hour) shall be based on--
    1. Historical data on the public water system, if available from the water system. These data shall be representative of climatic conditions that affect demand and source. If historical data is used, the entire distribution system hydraulics shall be calculated;
    2. If such historical data from the public water system are not available, data from a comparable water system may be used; or
    3. If neither historical nor comparable water system data are available, the following information shall be used for design purposes:

       Instantaneous Peak Flow = Domestic Peak Flow* + Lawn/Garden Irrigation Peak Flow + Commercial, Larger Users, Confined Feeding Operations

       *Domestic peak flow should be calculated as the greater of:
       1. One gallon per minute per connection, or
       2. Peak = 12(number of connections)$^{0.515}$.

    4. Other peak flow criteria may be used in lieu of the criteria listed in the

preceding item (1.1.2.f.3.) if the engineer provides adequate justification; for example, rural water districts may calculate domestic peak flow as the greater of 0.75 gallons per minute per connection or
Peak = 9(number of connections)$^{0.515}$.

g. Maximum day flow shall be based on:
   1. Historical data if these data are available from the public water system. This data shall be representative of climatic conditions that affect demand and source);
   2. If historical data are not available, data from a comparable system may be used; or
   3. If neither historical or comparable data are available, the following data may be used for design purposes:

      Maximum Day Flow = 150% of Average Day Flow.

   4. Other maximum day flow criteria may be used in lieu of this criteria in 1.1.2.g.3. if the engineer gives adequate justification.

1.1.3. Alternate plans

Where two or more solutions exist for providing public water supply facilities, each of which is feasible and practicable, discuss the alternate plans. Give reasons for selecting the solution recommended, including financial considerations, and a comparison of the certification level of water system operator required.

1.1.4. Soil, ground water conditions, and foundation problems

The engineering report shall specifically address whether the native soils are suitable for main bedding and backfill and note the extent that crushed stone, gravel or other purchased bedding/backfill will be needed, along with estimated costs. The report shall also address the potential for rock excavation in the various soils encountered, along with estimated costs.

1.1.5. Flow requirements

Flow requirements, including:

a. Hydraulic analyses based on flow demands and pressure requirements (see Chapter 8 of this document); and
b. Fire flows, when fire protection is provided, design shall be based on the Insurance Services Office (ISO) Fire Flow Criteria.

1.1.6. Sources of water supply

Describe the proposed source or sources of water supply to be developed, the reasons for their selection, and provide information as follows:

1.1.6.1. Surface water sources

Including where pertinent:

a. Hydrological data, stream flow, and weather records;
b. Safe yield design as described in section 3.1. of this document;
c. The maximum flood flow and the safety features of the spillway and dam, shall be based on the design criteria of the Missouri Dam and Reservoir Safety Council, regardless of the height of the dam;
d. A description of the watershed, noting any existing or potential sources of contamination (such as highways, railroads, chemical facilities, farming operations, etc.) which may affect water quality, a discussion of land use practices, and provisions for erosion and siltation control structures;
e. Summarized quality of the raw water, with special reference to fluctuations in quality, changing meteorological conditions, etc.; and
f. Source water protection issues or measures that need to be considered or implemented.

1.1.6.2. Ground water sources

a. Consolidated formation groundwater is generally available in very large quantities in southern and central Missouri and withdrawal is not regulated. However, large withdrawals may reduce the volume available in localized areas. The purpose of the hydrogeologic report is to provide information to the public water supply so that rational decisions can be made on location of wells, the possible civil liability of de-watering neighbors, and the practicality of expanding groundwater withdrawal from an ever widening circle versus switching to surface or alluvial sources;
b. The department shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and groundwater development. The engineering report shall include-
    1. A legal description of sites under consideration;
    2. Advantages of the selected site;
    3. Elevations with respect to surroundings;
    4. Probable character of formations through which the source is to be developed**;**
    5. Geologic conditions affecting the site; for example, any existing sinkholes, caves, test holes, abandoned wells, or anticipated interference between proposed and existing wells. This information can be obtained from the department's Geological Survey and Resource Assessment Division. Water supplies which withdraw or propose to withdraw 2,000,000 gallons per day (2 MGD) or more from wells in consolidated formations and public water supplies that are contiguous with other public supplies which together withdraw or propose to withdraw 2,000,000 gallons per day (2 MGD) or more from wells in consolidated formation, should submit a hydrogeologic report bearing the seal of a geologist registered in Missouri for each consolidated formation well project;

6. A summary of source exploration, test well depth, and method of construction, placement of liners or screen, test pumping rates and their duration, location, sieve analysis**,** water levels and specific yield, and water quality;
7. Existing wells within 1,000 feet radius of the proposed well site, giving their depths, protective casing depths, capacities, and location;
8. Sources of possible contamination within 1,000 feet; such as sewers and sewerage facilities, highways, railroads, landfills, outcroppings of consolidated water-bearing formations, chemical facilities, waste disposal wells, etc;
9. Depths of any known aquifers that will reduce well yield if penetrated;
10. Total depth of all known water bearing aquifers; and
11. Wellhead protection measures being considered.

1.1.7. New Technology

The technologies provided in these design standards are generally based on standards of the American Water Works Association, Recommended Standards for Water Works (commonly called "Ten States Standards"), and other nationally recognized standards. These technologies have a long history of use and can be reasonably expected to perform satisfactorily. However, it is the policy of the department to encourage new technologies for the production, treatment, and distribution of drinking water while continuing to protect the public health.

Any public water system proposing a new technology not addressed in these design standards shall provide and meet the following additional requirements in this subsection.

1.1.7.1. Engineering Report--Additional Requirements for New Technology

a. Complete description of the new technology including the scientific principles upon which the technology is based.
b. A statement indicating if the technology is currently protected by U.S. patents or is otherwise proprietary.
c. Results of full scale operations at other public water systems, with water similar to that of the public water system proposing the installation. These pilot studies shall:
    1. Have protocols including proposed testing parameters approved by the department prior to initiating the pilot study;
    2. Be done in a manner that will assure an acceptable quality of finished water will be produced through all seasonal water quality variations of the source water;
    3. Include a research of historic data to determine the extremes of water quality that may be encountered and the research results submitted in the results of the pilot study submitted with the engineering report;

4. Be conducted under the same operating parameters as the proposed full scale system;
5. Include an assessment of the costs of operation, replacement, and maintenance to be included in the results of the pilot study submitted with the engineering report; and
6. Be done in a manner to show repeatability of performance under the same operating conditions and the effects of long term operation.

d. The expected design life of each equipment component used in the new technology and the present day replacement cost of each component including both material cost and labor cost.

e. A complete description of the training needed for public water system personnel to operate and maintain the new technology including the number of days of training and the cost of training. If initial training is provided with the purchase price, the cost of training additional operators or maintenance personnel must be identified to cover personnel turnover.

f. The estimated number of minutes or hours needed per day, week, month, quarter, or year (as appropriate) including any down time expected to operate and maintain the components of the new technology. Any expected maintenance or repairs that must be done by vendor or factory personnel must also be identified along with costs, frequency, and down-time.

g. The estimated costs of operating and maintaining the new technology.

h. A complete description of standard technology including detailed cost estimates of material, labor, engineering, and contingency that would be needed to replace the new technology in the event the new technology is found to be ineffective.

i. A complete list of operating records, maintenance records, cost records, and testing protocol needed to evaluate the performance of the new technology.

1.1.7.2. Financial Certification.

The public water system's chief financial officer (or equivalent official if appropriate) shall provide written certification to the department that the system has financial resources that are adequate to operate and maintain the new technology and to replace the new technology with standard technology should the new technology be found to be ineffective. This certification shall include the nature of the financial resources, which may include but is not limited to: cash reserves in bank accounts or U.S. Government securities, other investments (stocks, bonds, mutual funds, precious metals, etc.), local bonds passed for this project but left in reserve to cover this contingency, binding agreement with a government funding agency to provide the funding needed to replace the new technology if it

proves ineffective, a performance bond meeting the conditions noted in the Performance Contract, or projected annual operating fund surpluses.

1.1.7.3. Performance Contract.

The public water system shall enter into a contract with the department that includes the following elements (A less stringent method would be a written certification instead of a contract):

a. The new technology shall be deemed ineffective if use of the technology results in a maximum contaminant level violation, action level violation, or treatment technique violation listed in 10 CSR 60 during any three months during a running 12-month period over the life of the performance period;

b. The new technology shall be deemed ineffective if use of the technology results in water outages or pressure reduction below 20 pounds per square inch gage (20 psig) during any three months during a running 12-month period over the life of the performance period;

c. The public water system shall maintain financial resources to replace the new technology with standard technology during the life of the contract. The reserve funds needed shall be initially based on the standard technology cost estimate from the engineering report and shall be increased annually for inflation using the federal consumer price index (or other suitable index);

d. The public water system will provide the operation and maintenance, including operator and maintenance personnel training, as outlined in the engineering report;

e. The public water system will collect and record all operation, maintenance, and cost records and perform all analysis outlined in the engineering report;

f. The public water system shall obtain the services of a professional engineer registered in Missouri to oversee data collection, record keeping, and provide a complete engineering analysis of the new technology after one year of operation, after the performance period is completed, and (if needed) following the department issuing a preliminary intent to declare the technology ineffective for this public water system. The professional engineer shall submit two copies of the engineering analysis to the department within six months of the end of the first year, within six months of the end of the performance period, and within six months of the department issuing a preliminary intent to declare the technology ineffective for this public water system. This engineering analysis shall evaluate the effectiveness of the new technology for its intended purpose and list all data and calculations supporting this evaluation, note any problems with operation or maintenance and including how, when, or if these problems were solved, note actual times spent operating and maintaining the new technology and compare these with those estimated in the engineering report, calculate costs of operating and

maintaining the new technology and compare these with those estimated in the engineering report, complete a reassessment of the expected life of major components of the new technology, include the engineer's conclusion as to whether or not this technology was effective for this public water system and include the engineer's recommendation (with any reservations) as to whether or not this technology should be widely approved for similar application;

g. If the public water system has maximum contaminant level violations, action level violations, treatment technique violations, or low pressure violations at the frequency noted above in items a. and b., that, in the department's opinion, could be the result of use of the new technology, the department shall issue a preliminary intent to declare the new technology ineffective for this public water system. The public water system shall then submit the engineering evaluation within the time frame noted above in item f.;

h. The department shall review the engineering evaluation and conduct other investigations as it deems necessary including, but not limited to, investigations by department employees or contractors, invitations to submit analysis from the vendor, manufacturer, and original project engineer (if different from the evaluation engineer). Within six months of submittal of the engineering evaluation by the public water system, the department shall make a formal determination of whether or not the new technology is ineffective for this public water system; and

i. If the department formally determines the new technology is ineffective for this public water system, the public water system shall:
    1. Within 180 calendar days, submit engineering plans and specifications prepared by a professional engineer registered in Missouri and a completed construction permit application to the department for replacing the new technology with the standard technology identified in the original engineering report;
    2. Within 30 calendar days of receipt of any request from the department for additional information or changes in the engineering plans and specifications, the public water system shall submit these modifications to the department;
    3. Within 180 calendar days of the department's approval to construct, the public water system shall construct the new facilities; and
    4. Within 21 calendar days of completion of construction, the public water system shall submit to the department certification by the professional engineer stating that the project has been substantially completed in accordance with the approved plans and specifications.

1.1.7.4. Performance Period.

The length of the performance period shall be the lesser of 60 months or the expected life of the major components of the new technology. The life of the contract shall be the performance period plus 12 months, which includes six months for the engineering analysis and six months for the department's final determination of effectiveness.

1.1.7.5. (no title)

Initially, the department will approve only one project for a particular new technology statewide. After the department completes review of the one year engineering evaluation of this first project, the department may approve an additional nine projects for a particular new technology statewide. If any project is formally declared to be ineffective, all approvals shall cease until the department reassesses the new technology and determines if the failure was site specific or more general.

1.1.7.6. (no title)

After the completion of ten successful projects for a particular new technology and department review of all engineering evaluations, the department may promulgate design regulations allowing the new technology to become standard technology or may allow additional projects to gather more information if needed. Ultimately, the department will either promulgate regulations making the new technology standard technology or will declare the new technology inappropriate for use in Missouri.

1.1.8. Project Sites.

The area and approximate geometry of the proposed site shall be identified and the adequacy for adding additional facilities on the site, and for providing adequate security. To the extent practical, all new or expanded water systems shall not be located on sites:

a. That are subject to a significant risk from earthquakes, floods, fires, pollution or other disasters which could cause a breakdown of the public water system or a portion of the system, and, except for intake structures, are within the floodplain of a 100-year flood where appropriate records exist;

b. That are in the proximity of residences, industries, and other establishments; and

c. With any potential sources of pollution or other factors that may influence the quality of the supply or interfere with effective operation of the water works system, such as sewage absorption systems, septic tanks, privies, cesspools, sinkholes, sanitary landfills, refuse and garbage dumps.

1.2. Plans.

Plans for water systems shall be no larger than standard size 24 inches by 36 inches.

1.2.1. Plans shall include:

a. Suitable title and index;
b. The name of the municipality, or other entity or person responsible for the water supply;
c. Scale, in feet;
d. North point;
e. U.S.G.S. datum used, critical mean sea level (msl) elevations for new and existing tanks determined from surveys beginning at USGS or department elevation monuments and copies of the survey;
f. Legible prints suitable for reproduction;
g. Date, name, and address of the designing engineer;
h. Imprint of professional engineer's seal in conformance with State of Missouri's engineering registration requirements;
i. Boundaries of municipality, water district, or area to be served;
j. Location and size of existing water mains;
k. Location and nature of existing water system structures and appurtenances affecting the proposed improvements, noted on one sheet;
l. Location and description of existing and/or proposed sewerage system;
m. Location of proposed water mains and water system structures, with size, length and identity;
n. Contour lines at suitable intervals; and
o. Names of streets and roads.

1.2.2. Detailed plans, including:

a. Stream crossings, providing profiles with elevations of the streambed, and the normal and extreme high and low water levels;
b. Profiles, where necessary, having a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than ten feet to the inch, with both scales clearly indicated. (Note: This does not apply to entire distribution systems.);
c. Location and size of the property to be used for the water works development with respect to known references such as roads, streams, section lines, or streets;
d. Topography and arrangement of present or planned wells or structures, with contour intervals not greater than two feet;
e. One hundred-year flood plain or elevations of the highest known flood level, floor of the structure, upper terminal of protective casings and outside surrounding grade, using United States Coast and Geodetic Survey, United States Geological Survey or equivalent elevations where applicable as reference;
f. Plat and profile drawings of well construction, showing the diameter and depth of drill holes and casings; liner diameters; grouting depths; elevations and designation of geological formations; water levels and other details to describe the proposed well completely;

g. Location of all existing and potential sources of pollution within 1,000 feet of the source, and within 300 feet of underground treated water storage facilities;
h. Size, length, and identity of sewers, drains, and water mains, and their locations relative to plant structures;
i. Schematic flow diagrams and hydraulic profiles showing the flow through various plant units;
j. Piping in sufficient detail to show flow through the plant, including waste lines;
k. Locations of all chemical storage areas, feeding equipment, and points of chemical application;
l. All appurtenances, specific structures, equipment, water treatment plant waste disposal units, and points of discharge having any relationship to the plans for water mains and/or water system structures;
m. Locations of sanitary or other facilities, such as lavatories, showers, toilets, floor drains, etc.;
n. Locations, dimensions, and elevations of all proposed plant facilities;
o. Locations of all sampling taps; and
p. Adequate description of any features not otherwise covered by the specifications.

1.3. Specifications.

Complete, detailed technical specifications shall be supplied for the proposed project, including:

a. A description of how existing water system facilities will continue in operation during renovation or construction of additional facilities to minimize interruption of service;
b. The specification of laboratory facilities and equipment;
c. The number and design of chemical feeding equipment;
d. A description of materials or proprietary equipment for sanitary or other facilities including necessary cross-connection protection;
e. The specification of manufactured products such as pipe, valves, fittings, hydrants, steel, Portland cement, etc. by the appropriate national standard, sufficient to differentiate the exact product. Any stamp or marking required to identify the product as meeting the national standard and an affidavit from the manufacturer stating that the product meets the national standard. The standard names, number, effective date, publication date, name and address of the organization issuing the standard shall identify the national standard. Specifications for manufactured products may also include the complete detailed national standard at the discretion of the engineer;
f. All procedures, methods, testing requirements, and products except manufactured products noted in paragraph 1.3.e. above, specified by the appropriate national standard and all details of the national standard needed to properly construct the water system component shall be included in the specifications. The standard

name, number, effective date, publication, name and address of the organization issuing the standard shall identify the national standard; and

g. Where performance specifications are used, shop drawings must be provided.

1.4. Summary of Design Criteria.

A summary of complete design criteria shall be submitted for the proposed project, including but not limited to the following:

a. Long-term dependable yield of the source of supply;
b. Reservoir surface area, volume, and a volume-versus-depth curve;
c. Area of watershed;
d. Estimated average and maximum day water demands for the design period;
e. Number of proposed services;
f. Fire fighting requirements;
g. Flash mix, flocculation and settling basin capacities;
h. Retention times;
i. Unit loadings;
j. Filter area and the proposed filtration rate;
k. Backwash rate; and
l. Chemical feeder capacities and ranges.

1.5. Additional Information.

The department may require additional information, which is not part of the construction drawings, such as head loss calculations, proprietary technical data, copies of deeds, copies of contracts, shop drawings, etc.

1.6. Revisions to Approved Plans.

a. Any deviation from approved plans or specifications affecting capacity, hydraulic conditions, operating units, the functioning of water treatment processes, or the quality of water to be delivered must be approved in writing before such changes are made.
b. Revised plans or specifications shall be submitted to the department for review and approval before any construction work affected by such changes is started.

1.7. Final Approval of Construction.

a. Final construction approval must be obtained from the department for all projects for which approval is required before that project is placed into service.
b. Upon completion of the construction, the engineer must:
    1. Notify the department and establish a mutually satisfactory time for making a final inspection, certify in writing that the construction is substantially completed in accordance with approved plans and specifications and change orders**;**
    2. Submit two copies of as-built plans to the department;
    3. Show that water quality is acceptable to the department; and

4. Submit the final cost of the project with all components of cost identified.

c. In larger projects, an interim (partial) approval may be secured for the completed parts of the water system before they are placed in service.

1.8. Supervised Program.

a. A supplier of water may apply for an owner-supervised program in lieu of submitting plans and specifications for expansion or modification of an existing water distribution system.

b. A written request to the Department of Natural Resources for approval of a supervised program shall include the following information:

1. An engineer-prepared report or a master plan showing the proposed waterlines over at least the next five years, along with engineering rationale, including hydraulic analyses, for sizing and locating the lines. The engineering report shall discuss adequacy of present water system with regard to the source, storage and existing distribution piping, problems that need to be resolved (leaks, low pressures, etc.), and fire protection needs (if applicable). A priority listing of proposed improvements along with cost estimates should also be included in the engineering report;
2. A current layout map, or maps, of the distribution system (standard size 24" x 36"). The map(s) shall show waterline sizes (existing and proposed), location of valves, fire hydrants and flushing devices, along with street names;
3. Adoption of a minimum pipe size for waterline replacements not otherwise shown on the master plan which shall maintain a minimum pressure in accordance with Chapter 8 of this document;
4. Examples of permanent records and drawings of the distribution system including lines, valves, hydrants and cleanouts;
5. Technical specifications prepared by an engineer covering construction materials, installation, and disinfection procedures in accordance with American Water Works Association standards;
6. Typical detail drawings by an engineer of special crossings, meter settings, valve settings, hydrant settings, cleanouts, thrust blockings, etc.;
7. A brief statement about qualifications of the person responsible for construction inspection;
8. A description of how permanent records and drawings will be provided. If permanent records and drawings are to be prepared by a consulting engineer, a copy of the agreement with the firm shall be provided; and
9. Examples of inspection forms to be used to inspect water mains and appurtances.

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Chapter 2 - General Design Considerations

2.0. General.

The design of a water supply system or treatment process encompasses a broad area. Application of this chapter depends on the type of system or process involved.

2.1. Design Basis.

The system shall be designed for maximum day demand at the design year.

2.2. Plant Layout.

Design shall consider:

a. Functional aspects of the plant layout;
b. Provisions for future plant expansion;
c. Provisions for expansion of the plant waste treatment and disposal facilities;
d. Access roads, driveways, walks, and fencing;
e. Site grading and drainage;
f. Chemical delivery; and
g. Security of facilities.

2.3. Building Layout.

Design shall provide for:

a. Adequate ventilation, lighting, emergency lighting, heating, and floor drainage;
b. Dehumidification equipment, if necessary;
c. Accessibility of equipment for operation, servicing, and removal;
d. Flexibility of operation, convenience of operation, and operator safety;
e. Chemical storage and feed equipment in ~~a~~ separate rooms to reduce hazards and dust problems; and
f. Adequate facilities should be included for shop space and storage, consistent with the designed facilities.

2.4. Siting Requirements.

a. Site shall not be subject to a significant risk from floods, fires, pollution, or other disasters, which could cause a breakdown of the public water supply system or portion thereof.
b. Non-submersible intake pumping equipment and accessories shall be located or protected to at least four feet above the 100-year flood elevation or the highest flood elevation on record.
c. The department shall be consulted regarding any structure that may impede normal or flood stream flows.
d. In earthquake prone areas, structures should be designed to withstand earthquake effects.

e. The site will provide all-weather access road to all significant facilities.

2.5 Security Measures

a. All water system facilities shall be designed to include measures to provide protection against vandalism, sabotage, terrorist acts, or access by unauthorized personnel. These protection measures shall include:
   1. Locked security doors;
   2. Windows sized or barred to prevent human entrance; and
   3. Security fencing around vulnerable areas of drinking water facilities (for example, wellheads, manholes, pumphouse, treatment buildings and storage tanks).

b. Other items from the following list should be included as needed to provide security commensurable with the importance of the facility to the overall water supply and the probability of the security breach.
   1. Perform a vulnerability assessment to effectively uncover your system's vulnerable points in order to successfully secure your facility.
   2. Prepare (or update) an Emergency Response Plan. Plans should be reviewed annually and all employees must receive adequate training to effectively carry out the emergency plan, thereby becoming familiar and confident with their roles in an emergency situation.
   3. Post emergency contact numbers at your facilities, in your consumer confidence reports, customer bills, web pages and any other highly visible area such as the office, pump-house, and on your vehicles. All personnel should have updated emergency contact numbers, which should be shared with your local law enforcement and response officials.
   4. Get to know your local law enforcement and ask them to add your facilities to their routine rounds. Practice emergency response procedures with local law enforcement, emergency responders and public health officials.
   5. Lock all access points to your facility (for example, access gates, doors, windows, hatches, finished water). Also, lock monitoring wells to prevent vandals or terrorists from pouring contaminants directly into ground water near your source. Set alarms to indicate illegal entry.
   6. Install motion activated lights around the perimeter of the pump-house, treatment facility and parking lot.
   7. Limit access to your water system. Do not allow anyone unassociated with your system to enter or wander around your facility. Verify the identity of delivery people. Request strangers to leave, or call local law enforcement if you have trespassers.
   8. Monitor water quality aggressively and be observant for unusual conditions including signs of intrusion and/or contamination (unusual water color, odors, sheens, fish kills and sudden increased chlorine demand).
   9. In the event of an emergency, follow your emergency response plan and contact the Public Drinking Water Program.

2.6. Electrical Controls.

Main switch gear electrical controls shall be located above grade, and in areas not subject to flooding.

2.7. Standby Power.

For the system's own protection, standby power or an alternate power source should be provided so that water may be treated and/or pumped to the distribution system during power outages to meet average day demand. Systems serving a population of 3,300 or greater shall have arrangements in place for standby or backup power and shall include these arrangements in their emergency operating plan.

2.8. Laboratory Equipment.

Each public water supply shall have its own equipment and facilities for routine laboratory testing necessary to ensure proper operation. Laboratory equipment selection shall be based on the characteristics of the raw water source and the complexity of the treatment process involved. Laboratory test kits that simplify procedures for making one or more tests may be acceptable. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately certified laboratory in accordance with methods approved by the department. Persons designing and equipping facilities for which laboratory certification by the department is desired shall confer with the department before beginning the preparation of plans or the purchase of equipment. Methods for verifying adequate quality assurance and for routine calibration of equipment shall be provided.

2.8.1. Testing equipment.

a. Surface water supplies:
   1. Shall have a bench model Nephelometric turbidimeter to monitor entry point to the distribution system;
   2. Shall have continuous Nephelometric turbidity monitoring and recording equipment on each filter located to monitor effluent and filter to waste;
   2. Shall have electrode pH meter;
   3. Shall have equipment necessary to perform jar test;
   4. Shall have titration equipment for both hardness and alkalinity; and
   5. Should provide the necessary facilities for microbiological testing of water from both the treatment plant and the distribution system.

b. Groundwater supplies, where pertinent:
   1. Shall have test equipment capable of accurately measuring iron and manganese to a minimum of 0.05 milligram per liter;
   2. Shall have electrode pH meter;
   3. Shall have titration equipment for both hardness and alkalinity; and
   4. With lime softening facilities, should have a Nephelometric turbidimeter.

c. Public water supplies that**:**
   1. Chlorinate shall have test equipment for determining both free and total

chlorine residual by methods in "Standard Methods for the Examination of Water and Wastewater";
2. Fluoridate shall have test equipment for determining fluoride by methods in "Standard Methods for the Examination of Water and Wastewater"; and
3. Feed polyphosphates and/or orthophosphates shall have test equipment capable of accurately measuring phosphates from 0.1 to 20 milligrams per liter.

2.8.2. Physical facilities.

Sufficient bench space, adequate ventilation, adequate lighting, electrical receptacles, storage room, laboratory sink, and auxiliary facilities shall be provided. Air conditioning may be necessary.

2.9. Monitoring and Recording Equipment.

Water treatment plants with a capacity of 0.5 mgd or more should be provided with continuous monitoring and recording equipment to monitor water being discharged to the distribution system as follows:

a. Plants treating surface water and plants using lime for softening should have the capability to monitor and record free chlorine residual and pH. In addition, continuous monitoring of entry point disinfection residuals shall be provided for systems with a service population greater than 3,300 people. Monitoring of the parameters to evaluate adequate CT disinfection, such as residuals, pH and water temperature, should be provided; and
b. Plants treating ground water using iron removal and/or ion exchange softening should have the capability to monitor and record free chlorine residual.

2.10. Plant Sample Taps.

a. Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment.
b. Taps shall be consistent with sampling needs and shall not be of the petcock type.
c. Taps used for obtaining samples for bacteriological analysis shall be of material that resist flaming, smooth-nosed type without interior or exterior threads, shall not be of the mixing type, and shall not have a screen, aerator, or other such appurtenances.

2.11. Facility Water Supply.

a. The facility water supply service line and the plant finished water sample tap shall be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved.
b. There shall be no cross-connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw or partially treated water.

2.12. Wall Castings.

Consideration shall be given to providing extra wall castings built into the structure to facilitate future uses whenever pipes pass through walls of concrete structures.

2.13. Meters.

All water supplies shall have an acceptable means of metering the raw water flow, finished water flow, flow through the treatment plant, and treatment plant service flow.

2.14. Piping Color Code.

a. To facilitate identification of piping in plants and pumping stations the color scheme in Table 1 is recommended.

Figure 1 - Piping Color Code

TYPE OF PIPE	PIPE COLOR
WATER LINES	
Raw	Olive
Settled or Clarified	Aqua
Finished or Potable	Dark Blue
CHEMICAL LINES	
Alum or Primary Coagulant	Orange
Ammonia	White
Carbon Slurry	Black
Caustic	Yellow with Green Band
Chlorine (Gas and Solution)	Yellow
Fluoride	Light Blue with Red Band
Lime Slurry	Light Green
Ozone	Yellow with Orange Band
Phosphate Compounds	Light Green with Red Band
Polymers or Coagulant Aids	Orange with Green Band
Potassium Permanganate	Violet
Soda Ash	Light Green with Orange Band
Sulfuric Acid	Yellow with Red Band
Sulfur Dioxide	Light Green with Yellow Band
WASTE LINES	
Backwash Waste	Light Brown
Sludge	Dark Brown
Sewer (Sanitary or Other)	Dark Gray
OTHER	
Compressed Air	Dark Green
Gas	Red
Other Lines	Light Gray

In situations where two colors do not have sufficient contrast to easily differentiate

between them, a six-inch band of contrasting color should be on one of the pipes at approximately 30-inch intervals. The name of the liquid or gas should also be on the pipe. In some cases, it is also advantageous to provide arrows indicating the direction of flow.

2.15. Disinfection.

All wells, pipes, tanks, and equipment which can convey or store potable water shall be disinfected in accordance with the current AWWA procedures. Plans or specifications shall outline the procedure and include the disinfectant dosage, contact time, and method of testing the results of the procedure.

2.16. Manuals and Parts List.

An operation and maintenance manual including a parts list and parts order form shall be supplied to the water system as part of any proprietary unit installed in the facility. Written instruction for the start-up of the plant or pumping station shall be provided to the water system owner.

2.17. Other Considerations.

Consideration must be given to the design requirements of other federal, state, and local regulatory agencies for items such as safety requirements, special designs for the handicapped, plumbing and electrical codes, construction in a flood plain, etc.

2.18. Automation.

The department encourages measures, including automation, which assist operators in improving plant operations and surveillance functions. Automation of surface water treatment facilities to allow unattended operation with off-site control presents a number of management and technological challenges that must be overcome before an approval can be considered. Each facet of the plant facilities and operations must be fully evaluated to determine what on-line monitoring is appropriate, what alarm capabilities must be incorporated into the design and what staffing is necessary. Consideration must be given to the consequences and operational response to treatment challenges, equipment failure and loss of communications or power.

The engineering report to be submitted to the department for review must cover all aspects of the treatment plant and automation system including the following information/criteria:

1. Identification of all critical features in the pumping and treatment facilities that will be electronically monitored, have alarms and can be operated automatically or off-site via the control system. Include a description of automatic plant shutdown controls with alarms and conditions that would trigger shutdowns. Dual or secondary alarms may be necessary for certain critical functions;

2. Provision for automated monitoring of all critical functions with major and minor alarm features. Automated plant shutdown is required on all major alarms. Automated remote startup of the plant is prohibited after shutdown due to a major alarm. The control system must have response and adjustment capability on all minor alarms. Built-in control system challenge test capability must be provided to verify operational status of major and minor alarms;
3. The plant control system that has the capability for manual operation of all treatment plant equipment and process functions;
4. A plant flow diagram that shows the location of all critical features, alarms and automated controls to be provided;
5. Description of off-site control station(s) that allow observation of plant operations, receiving alarms and having the ability to adjust and control operation of equipment and the treatment process;
6. Description of optimal staffing for the plant design, including meeting requirements in 10 CSR 60-14.010 for certified operators; an on-site check at least once per day by a certified operator to verify proper operation and plant security; and sufficient appropriate staffing to carry out daily on-site evaluations, operational functions, and maintenance and calibration of all critical treatment components and monitoring equipment and weekly checks of the communication and control system to ensure reliability of operations. Challenge testing of such equipment should be part of normal maintenance routines;
7. Description of operator training planned or completed in both process control and the automated system;
8. Operations manual, which gives operators step-by-step procedures for understanding and using the automated, control system under all water quality conditions. Emergency operations during power or communications failures or other emergencies must be included;
9. A plan for a 6-month or more demonstration period to prove the reliability of procedures, equipment and surveillance system. A certified operator must be on duty during the demonstration period. The final plan must identify and address any problems and alarms that occurred during the demonstration period. Challenge testing of each critical component of the overall system must be included as part of the demonstration project;
10. A schedule for maintenance of equipment and critical parts replacement;
11. Provision for sufficient finished water storage to meet system demands and CT requirements whenever normal treatment production is interrupted as the result of automation system failure or plant shutdown; and
12. Provision for ensuring security of the treatment facilities at all times. Incorporation of appropriate intrusion alarms must be provided which are effectively communicated to the operator in charge. See section 2.5 Security Measures.

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Chapter 3 - Source Development

3.0. General.

In selecting the source of water to be developed, the design engineer must prove that an adequate quantity of water will be available. The proposed groundwater or surface water supply must be adequate for future water demands during the design period. Water that is to be delivered to the consumers will meet the current requirements of the department with respect to microbiological, physical, chemical and radiological qualities. Each water supply should take its raw water from the highest quality and sustainable source that is economically reasonable and technologically possible.

3.1. Surface Water.

A surface water source includes all tributary streams and drainage basins, natural lakes, and artificial reservoirs above the point of water supply intake.

3.1.1. Quantity.

3.1.1.1. Reservoir Storage Volume.

a. Reservoir storage volume shall provide a reasonable surplus for reserve storage and anticipated growth. A reasonable amount of surplus reserve storage should be considered in order to maintain public confidence in the reliability of supply at predicted depletion levels during a prolonged severe drought. A minimum of 120 days surplus reserve storage should be considered.
b. Reservoir storage volume shall be adequate to compensate for all losses such as silting, evaporation, seepage, and stagnation.

3.1.1.2. Reservoir Capacity.

a. When multiple water sources are provided, the amount of water needed from the proposed reservoir shall be stated and that amount plus water losses due to sediment, evaporation, seepage, and stagnation shall be used to design the reservoir capacity.

b. The capacity of a water supply reservoir shall be determined by using a reservoir operations model such as the USDA Natural Resource Conservation Service's Procedures for Determining Runoff and Reservoir Operation Study. A reservoir study shall be conducted for the drought of record using future design period demand for the water system. The design draft shall include water losses due to sediment,

evaporation, seepage, and stagnation as well as the predicted water system demand. Losses due to sediment shall be the accumulated loss predicted at the end of the design period of the reservoir. Climatic data such as precipitation and evaporation used shall be as specific to the proposed reservoir site as is possible. The usable quantity of water in a reservoir shall be sufficient to provide carryover storage at all design future demands and shall include a sufficient reserve to maintain public confidence in the reliability of supply at predicted depletion levels. Water supply availability and storage capacity must meet future water demands of all water users through the multiyear drought of record, presently from 1953 through 1958.

3.1.1.3. River or Stream as the Sole Source of Water.

When a river or stream is to be used as the sole source of water, the flow in the river or stream shall exceed the current registered and future downstream uses, instream flow recommendations, usually the 7 day Q 10 flow rate, and the design year future water system demand. Historical data must be used to determine that stream flows are adequate. Where the nearest gauging station is downstream of the intake site, a drainage area ratio or other approved method to represent the intake location must adjust the flow data. Data from an upstream station may be used. For streams where data does not cover the drought of record, data from similar streams may be used to correlate or predict stream flows, with department approval.

The necessary permits and approvals to install an intake into a stream or river shall be obtained. The conditions on a permit may significantly affect the quantity and rate that may be pumped and the carryover storage required. The usable capacity of the raw water storage reservoirs shall provide carryover storage for the worst case conditions of record. Design demand analysis from the stream or river shall meet all predicted system demands, shall meet permit conditions, shall include the ability to refill the off-stream reservoirs and shall account for evaporation and seepage from all the reservoir storage structures.

3.1.1.4. Supplemental Pumping.

Where pumping is used to supplement runoff to a water supply reservoir, a reservoir operation study shall be developed to determine if stream flows, runoff and carryover storage are adequate. The design demand shall include water losses due to evaporation and seepage, all reservoir design life sediment storage, dead pool, losses and all the predicted water system demand. A written pumping plan shall be provided that includes the minimum lake level that will be allowed before pumping is initiated, and

the recommended pumping rates and quantities. The pumping plan must take into account water quality concerns, such as increased settable solids, turbidity, and microbiological and chemical constituents due to storm runoff events, thereby reducing the amount of available pumping.

3.1.2. Quality.

A sanitary survey and study shall be made of the factors, both natural and man-made, which may affect water quality in the water supply lake or reservoir. The design of a water treatment plant must consider the worst condition that may exist during the life of the facility. Such survey and study shall include, but may not be limited to:

a. Determining possible future uses of lakes or reservoirs;
b. Determining the owner's degree of control over the watershed;
c. Assessing the degree of hazard to the supply posed by agricultural, domestic or industrial contaminant sources including municipal and industrial wastewater treatment plants, and animal feeding operation lagoons, recreational and residential activities in the watershed and by the accidental spillage of materials that may be toxic, harmful, or detrimental to treatment processes;
d. Obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical, and radiological characteristics of the water;
e. Assessing the capability of the proposed treatment process to reduce contaminants to applicable standards;
f. Considerations of current, wind and ice conditions,
g. Development, to the extent possible, of a watershed protection plan; and
h. Identification of all possible point and non-point sources of contamination discharges.

3.1.3. Structures.

3.1.3.1. Intake structure design.

Design of intake structures shall provide for:

a. Withdrawal of water from more than one level if quality varies with depth;
b. Separate facilities for release of less desirable water held in storage;
c. Limiting the velocity of flow into the intake structure to a minimum, generally not to exceed 0.5 foot per second, where frazil ice may be a problem;
d. Occasional cleaning of the inlet line;
e. Adequate protection against rupture by dragging anchors, ice, etc.;
f. Ports located above the bottom of the stream, lake or reservoir, but at sufficient depth to be kept submerged at low water;
g. A diversion device capable of keeping large quantities of fish or debris

from entering an intake structure, where shore wells are not provided;

h. Where deemed necessary, provisions shall be made in the intake structure to control the influx of zebra mussels or other aquatic nuisances. Specific methods to control zebra mussels shall be approved by the Missouri Department of Natural Resources;
j. When buried surface water collectors are used, sufficient intake opening area must be provided to minimize inlet headloss. An entrance velocity of 0.1 feet per second is recommended. Particular attention should be given to the selection of backfill material in relation to the collector pipe slot size and gradation of the native material over the collector system; and
k. Devices restricting access to intakes.

3.1.3.2. Raw water pumping wells and transmission mains.

Raw water pumping wells and transmission mains shall:

a. Have necessary motors and electrical controls and non-submersible pumps and motors located above grade and protected from flooding as required by the department;
b. Be accessible but have devices restricting access to only authorized personnel;
c. Be designed against flotation;
d. Be equipped with removable or traveling screens before the pump suction well;
e. Provide for introduction of chlorine or other chemicals in the raw water transmission main if necessary for quality control;
f. Have valves and provisions for flushing or cleaning by a mechanical device and testing for leaks;
g. Have provisions for withstanding surges and be protected against damage by floating debris where necessary;
h. Not provide water services on raw water transmission mains to water treatment facilities or provide pressure tanks and additional pumps to adequately supply any services allowed; and
i. Provide meters on any water services on a raw water transmission main.

3.1.3.3. Raw water storage reservoir.

An off-stream raw water storage reservoir is a facility into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. Raw water storage reservoirs shall be constructed to assure that:

a. Water quality is protected by controlling runoff into the reservoir;
b. Dikes are structurally sound and protected against wave action and erosion;
c. Intake structures and devices meet the requirements of paragraph 3.1.3.1. of this document;

d. Point of influent flow is separated from the point of withdrawal; and
e. Separate pipes are provided for influent to and effluent from the reservoir.

3.1.4. Lakes and reservoirs.

3.1.4.1. Site preparation.

Site preparation shall provide, where applicable:

a. Removal of brush and trees to high water elevation;
b. Protection from floods during construction; and
c. Proper abandonment of all wells that will be inundated, in accordance with subparagraph 3.2.5.15. of this document.

3.1.4.2. Construction.

3.1.4.3.2. Construction shall require:

a. Silt basins and erosion control structures as a part of the lake design. Instead of providing additional lake volume for silt, silt catch basins should be provided;
b. Silt basin design that allows them to be drained and silt routinely removed from the basins; and
c. Sufficient fencing around the lake to prevent access to the lake by livestock.

3.1.4.2.1. Construction may require:

a. Approval from the appropriate regulatory agencies of the safety features for stability and spillway design;
b. A permit from an appropriate regulatory agency for controlling stream flow or installing a structure on the bed of a stream or interstate waterway;
c. A permit from the Department of Natural Resources' Water Pollution Control Program for land disturbance;
d. Restricted access to the dam; and
e. A 300-foot green belt around the perimeter of each water supply lake.

3.1.4.3. Water supply dams.

Water supply dams shall be constructed in accordance with the design guidelines of the Missouri Dam and Reservoir Safety Council.

3.1.4.4. Recreational uses of public water supply lakes.

Every supplier of water to a public water system shall secure the approval of the department before permitting the use of public water supply impoundments for recreational usage.

a. Regulated recreational activities are permitted when provisions for such activities are included in the original planning, construction, and approval of the impoundment and water treatment facilities.
b. Recreational activities proposed for existing impoundments will be appraised in the light of the effect on the primary purposes of the impoundment, the capability of the water treatment systems, the physical adaptability of the impoundment to the desired recreational use, and the maintenance of public confidence in the water supply.
c. Provisions shall be made for local enforcement of all rules and ordinances governing recreation. Rules must be posted and maintained in legible condition at conspicuous points in the impoundment area. If rules and ordinances cannot be effectively enforces, recreation shall not be provided.

3.2. Groundwater.

A groundwater source includes all water obtained from drilled wells that is not under the direct influence of surface water.

3.2.1. Quantity.

3.2.1.1. Minimum capacity.

The total developed groundwater source capacity shall equal or exceed the design maximum day demand.

3.2.1.2. Number of sources.

a. Because wells drilled into unconsolidated formations must be routinely removed from service for cleaning and redevelopment, all water systems served by these wells shall have more than one well and shall be capable of meeting maximum day demand with the largest producing well out of service.
b. Public drinking water systems serving 500 or more people shall have more than one well and shall be capable of meeting design maximum day demand with the largest producing well out of service.
c. Public drinking water systems serving less than 500 people should have more than one well and should be capable of meeting design maximum day demand with the largest producing well out of service. In determining the minimum number of wells needed, the supplier of water should consider such factors as the amount of system storage, the critical nature of businesses being served by the water system (for example, hospitals), and the amount of

water needed.

3.2.1.3. Auxiliary power.

a. When power failure would result in cessation of minimum essential service, sufficient power should be provided to meet average day demand through:
   1. Connection to at least two independent public power sources; or
   2. Portable or in-place auxiliary power.
b. When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, the pre-lubrication line shall be provided with a valved by-pass around the automatic control, or the automatic control shall be wired to the emergency power source.

3.2.2. Quality

3.2.2.1. Microbiological quality.

a. Tools, pumps, pipe, gravel pack material, drilling equipment and water used during drilling should be treated with a 200 milligrams per liter chlorine solution. Wells should be tested for any signs of iron or sulfur bacteria contamination after drilling. If possible, the water in the aquifer should be tested before drilling a production well to determine if iron or sulfur reducing bacteria are naturally present.
b. Disinfection of every new, modified or reconditioned groundwater source shall be:
   1. In accordance with the latest AWWA Standard A-100;
   2. Provided after completion of work if a substantial period elapses prior to test pumping or placement of permanent pumping equipment;
   3. Provided after placement of permanent pumping equipment; and
   4. Provided any time the pump or column pipe is removed or replaced.
c. After disinfection, one or more water samples shall be submitted to a laboratory certified by the department for microbiological analysis and the results reported to the department prior to placing the well into service**.** Before placing the well in service, water samples for microbiological analysis shall test absent for coliform bacteria on two consecutive days from wells drilled in consolidated formations. Water from most wells in unconsolidated formations is sent to a water plant for treatment and disinfection. Microbiological analysis of water samples from these wells shall

be done to determine the degree and extent of microbiological contamination present but the presence of coliform bacteria is not grounds for rejection of these wells. However, tests for more than total coliform bacteria should be considered.

3.2.2.2. Physical and chemical quality.

a. Every new, modified, or reconditioned groundwater source shall be examined for applicable physical and chemical characteristics by tests of a representative sample in a laboratory certified by the department.

b. Samples shall be collected at the conclusion of the test pumping procedure and examined as soon as practicable (within the specified holding period).

c. Field determinations of physical and chemical constituents or special sampling procedures may be required by the department.

3.2.2.3. Radiological quality.

Each new or modified groundwater source shall be examined for radiological activity as required by the department.

3.2.3. Location.

3.2.3.1. Well location.

a. Prior to design and construction, the Department of Natural Resources Regional Office serving the area in which the well will be located shall be consulted regarding a proposed well location as it relates to the required separation between existing and potential sources of contamination and groundwater development.

b. The Department of Natural Resources' Geological Survey and Resource Assessment Division shall be consulted prior to design and construction regarding a proposed well location as it relates to required well depth and casing depth, for consolidated formations.

3.2.3.2. Isolation standards.

a. Unless the geology and aquifer hydraulics dictate greater or lesser distances, or unless the department approves a lesser distance based on the engineering report, acceptance of the well site, for new wells, shall be based on compliance with the radii in Table 2.

Figure 2 - New Well Isolation Radii

Source of Possible Contamination	**Minimum Isolation Radius**
Wastewater treatment plants, wastewater lagoons, chemical storage, landfills, petroleum storage tanks, or wastewater and solid waste disposal fields	300 feet
Manure storage area, unplugged abandoned well, graves, subsurface disposal field, sewage pumping station, building or yard used for livestock or poultry, privy, cesspool, or other contaminants that may drain into the soil	100 feet
Sanitary sewer lines, existing wells, pits sumps or holes, septic tanks, lakes or streams	50 feet
The right-of-way of federal, state, or county road	10 feet

b. Source water protection

(1) The owner of the well should control or own all the land within an isolation radius to the extent necessary to maintain minimum distances from potential sources of contamination after the well is constructed.

(2) The owner of the well should adopt a wellhead protection program and should encourage adjacent landowners to adopt voluntary restrictions on land use.

(3) Where legal authorities (such as a city council or county zoning authority) exist to provide ordinances, covenants, zoning, or other legally binding restrictions, the owner of the well should make every feasible effort to obtain legally binding restrictions to control or own all the land within an isolation radius to the extent necessary to maintain minimum distances from potential sources of contamination after the well is constructed.

c. Wells in unconsolidated formation will require greater isolation radii.

d. A well shall be located at least three feet horizontally from a building or any projection, except for a pumphouse.

e. No well shall be located within 15 feet of an overhead electric distribution line or 25 feet from an electric transmission line that is in excess of 50 kilovolts (kV) except for the underground electrical service line in the vicinity of an existing well or proposed well. Where there is a question of the voltage in an electric line, the 25-foot distance should be observed, or where less distance is required the utility company should be consulted for their recommendation for safe distances.

3.2.3.3. Other site location and security considerations.

a. The well shall be so located that the site will meet the requirements for sanitary protection of water as well as protection against fire, flood, vandalism, terrorist acts, or other hazards.

b. The well shall be elevated to a minimum of four feet above the 100-year return frequency flood elevation or four feet above the highest historical flood elevation, which ever is higher, or protected to such elevations.

c. The top of the upper terminal of the well shall be readily accessible to operating and maintenance personnel at all times unless the overall system design allows the well to be out of service for the period of inaccessibility.

d. The area around the well shall be graded to lead surface water drainage away from the well.

3.2.4. Testing and records.

3.2.4.1. Yield and drawdown tests.

Water discharged during a pumping test shall be conducted to the nearest surface water body, storm sewer or ditch in a manner that prevents property damage and that prevents re-circulation of discharged water into the aquifer being pumped.

3.2.4.1.1. For wells in consolidated formations, tests shall:

a. Be performed on every production well after construction or subsequent treatment and prior to placement of the permanent pump (wells in consolidated formations having a nominal casing diameter of less than eight inches may be exempted as approved by the department on a case by case basis);

b. Have the test methods clearly indicated in specifications;

c. Have a test pump capacity, at maximum anticipated drawdown, at least 1.5 times the quantity anticipated;

d. Provide for continuous pumping for at least 24 hours or until stabilized drawdown has continued for at least one hour when test pumped at 1.5 times the design pumping rate; other pumping test methods may be used if prior approval from the department is obtained;

e. Provide the following data:
   1. Test pump capacity vs. head characteristics;
   2. Static water level;
   3. Depth of test pump setting; and
   4. Time of starting and ending each test cycle; and

f. Provide recordings and graphic evaluation of the following at one-hour intervals or less as may be required by the department:

1. Pumping rate;
2. Pumping water level;
3. Drawdown; and
4. Water recovery rate and levels.

3.2.4.1.2. For wells in unconsolidated formations, yield and drawdown tests must produce the data necessary to determine the capacity of the well, aquifer characteristics, well efficiency, pumping rates, required distances between wells, pump installation depth settings and other factors that will be of value in the long term operation and maintenance of the well. These comprehensive tests require a minimum of one or two observation wells located 100 to 300 feet from the production well and at the same depth. Yield and drawdown tests shall:

1. Be done on every production well after construction but before placement of the permanent pump;
2. Be done using a pump with a capacity, at maximum anticipated drawdown, at least 1.5 times the quantity anticipated. Bailing, air blowing or air lifting shall not be used;
3. Be done using an accurate rate-of-flow, orifice or venturi meter;
4. Provide for measurement of water levels using either the airline method or the electric sonde method;
5. Be done according to one of the following methods:
   i. The Variable Rate Method: This method is done by setting the pump at the lowest producing zone and pumping at 1.5 times the design rate of the well until the pump breaks suction. If the pump does not break suction for a period of 24-hours, the test shall be completed as a continuous rate test. If the pump breaks suction, the rate shall be slowly decreased until the pumping level stabilizes approximately two feet above the pump intake for at least five minutes. Then the pumping rate shall be decreased 5% and the well pumped until the pumping level stabilizes for one hour. The pumping level shall be measured according to the following schedule:
      0 to 10 minutes - every minute;
      10 to 45 minutes - every 5 minutes;
      45 to 90 minutes - every 15 minutes;
      90 to 180 minutes - every 30 minutes;
      180 minutes to the end of the test - hourly.
      The discharge rate and drawdown thus established shall then be maintained for at least four hours.

This pumping rate shall be considered the available production rate of the well and the observed pumping level during the test shall be considered the production pumping level. The static water level shall be established before the start of the pumping test;

ii. The Constant Rate Method: This method is done by pumping the well at a discharge rate that is 1.5 times the design rate of the well with the test pump intake set five feet below the estimated lowest pumping level. Discharge shall be maintained within plus or minus 5% percent of this flow and shall be checked every ten minutes during the first hour of the test and at 30 minute intervals thereafter. The well shall be pumped for 24 hours or until the pumping level stabilizes for four hours. The static water level shall be established before the start of the pumping test. The pumping level shall be measured according to the following schedule:
0 to 1 minutes - every minute;
10 to 45 minutes - every 5 minutes;
45 to 90 minutes - every 15 minutes;
90 to 180 minutes - every 30 minutes;
180 minutes to the end of the test - hourly.
On completion of the pumping, recovery measurements shall be made according to this same schedule until full recovery is reached or the level stabilizes for at least four hours;

iii. The Step Continuous Composite Method: This method is done by setting the pump at the lowest producing zone and pumping the well at rates ½, ¾, 1, and 1½ times its design capacity. Discharge shall be maintained within plus or minus 5% percent of the designated flow. The static water level shall be established before the start of the pumping test. Measurements of pumping rate and water level shall be made every one minute for the first ten minutes of the test, every two minutes for the next ten minutes, every five minutes for the next 40 minutes, every 15 minutes for the next hour, every 30 minutes fort the next three hours, and hourly for the remainder of the pumping period. At each rate step, the well shall be pumped until the pumping level stabilizes for at least four hours or the pump breaks suction. Water

level in the well shall be allowed to recover to static or stabilize for one hour after each pumping step. After each increase in pumping rate the above measurement schedule shall be repeated. On completion of the pumping, recovery measurements shall be made according to this same schedule until full recovery is reached or the level stabilizes for at least four hours; or

iv. Aborted Test: Whenever continuous pumping at a uniform rate is specified, failure of the pump operation for a period greater than one percent of the elapsed pumping time shall require suspension of the test until the water level in the pumped well has recovered to its original level. If the water level does not recover to its original level, pump testing can resume if three successive water level measurements spaced 20 minutes apart show no rise in level; and

f. Provide written records and graphic evaluations of all times, static water levels, pumping rates, pumping water levels, drawdown, and water recovery rates and levels measured.

3.2.4.2. Geological data.

a. Geological data shall be determined from samples collected at five-foot intervals and at each pronounced change in formation.

b. For wells drilled in consolidated material, geological data shall be recorded and samples submitted to the Geological Survey and Resource Assessment Division.

c. For wells drilled into unconsolidated material, a detailed driller’s log of all wells and test holes associated with the public well shall be submitted in duplicate to the Public Drinking Water Program.

d. Geological data shall be supplemented with information on drill hole diameters and depths, assembled order of size and length of casing**,** screens and liners; grouting depths; formations penetrated, water levels, and location of any blast charges.

3.2.5. General well construction.

3.2.5.1. Minimum protected depths.

Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the department.

3.2.5.2. Special conditions for wells drilled into consolidated formations.

The depth of the permanent casing will be determined from the

examination of drill cuttings by the Geological Survey and Resource Assessment Division.

3.2.5.3. Special conditions for wells drilled into unconsolidated formations.

a. If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials but shall not extend any less than 20 feet below the original ground elevation.
b. If a sand or gravel aquifer is overlaid only by permeable soils, the permanent casing and grout shall extend to at least 20 feet below the original or final ground elevation, whichever is lower.
c. If a temporary or a surface casing is used, it shall be completely withdrawn as grout is applied. If the temporary or surface casing cannot be withdrawn, the driller must contact the appropriate department regional office for approval of a method to finish the well.

3.2.5.4. Drilling fluids and additives.

Drilling fluids and additives shall:

a. Not impart any toxic substances to the water or promote bacterial contamination;
b. Be acceptable to the department;
c. Shall be capable of being removed from the drill hole and formation so that they do not retard the capacity of the well; and
d. Use water for preparation that will not contaminate the aquifer.

3.2.5.5. Surface steel casing.

Surface steel casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal.

3.2.5.6. Permanent steel casing pipe.

Permanent steel casing pipe shall:

a. Be new pipe meeting AWWA Standard A-100, or ASTM or API specifications for water well construction;
b. Have minimum weights and thickness indicated in Table 3;
c. Have additional thickness and weight if minimum thickness is not considered sufficient to assure the reasonable life expectancy of a well;
d. Be capable of withstanding forces to which it is subjected; and
e. Have full circumferential welds or threaded coupling joints.

3.2.5.7. Gravel pack material.

a. Gravel pack materials shall:
   1. Be sized based on sieve analysis of the formation and copies of

sieve analyses of the water bearing formation and of the proposed gravel pack shall be submitted to the department for approval before the installing the gravel pack;

2. Be well-rounded particles, 95 percent siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement;
3. Have an average specific gravity of not less than 2.5;
4. Have uniformity coefficient not to exceed 2.5;
5. Have a gravel pack-to-formation sand ratio within the range of 6:1 to 4:1; and
6. Be disinfected with at least a 200 milligrams per liter chlorine solution, just before installation.

b. Gravel pack.

1. Gravel pack shall be placed in one continuous operation.
2. The annular space between the well screen and the hole shall be at least four inches to allow proper placement of gravel pack.
3. Gravel refill pipes, when used, shall be Schedule 40 steel pipe incorporated within the pump foundation and terminated with screwed or welded caps at least 12 inches above the pumphouse floor.
4. Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 1 1/2 inches of grout.
5. Gravel pack shall extend at least 20 feet above the well screen.
6. Protection from leakage of grout into the gravel pack or screen shall be provided.
7. Permanent inner casing and outer casings shall meet requirements of subparagraphs 3.2.5.5. and 6.

3.2.5.8. Packers.

Packers shall be of material that will not impart taste, odor, toxic substance or bacterial contamination to the well water. Lead packers shall not be used.

3.2.5.9. Screens.

Screens shall:

a. Be constructed of stainless steel;

b. Have size of openings based on sieve analysis of formation and/or gravel pack materials. Copies of sieve analyses of the water bearing formation and of the proposed gravel pack shall be submitted to the department for approval before the size of the screen is specified;

c. Have sufficient diameter and length to provide adequate specific capacity and a lower entrance velocity not to exceed 0.1 foot per

second. Lower entrance velocity is recommended for water of significant incrustating potential;

d. Be installed so that the pumping water level remains above the screen under all operating conditions;

e. Where applicable, be designed and installed to permit removal or replacement without adversely affecting watertight construction of the well;

f. Be provided with a bottom plate or washdown bottom fitting of the same material as the screen**;** and

g. Be capable of resisting the column and tensile loads and the collapse pressures imposed during installation and well development and imposed by the external geological forces**.**

3.2.5.10. Plumbness and alignment requirements.

a. Every well shall be tested for plumbness and alignment in accordance with the latest edition of AWWA Standard A-100.

b. The test method and allowable tolerance shall be clearly stated in the specifications.

c. If the well fails to meet these requirements, it may be accepted by the engineer**,** after consultation with the department**,** if it does not interfere with the installation or operation of the pump or uniform placement of grout.

3.2.5.11. Grouting requirements.

a. All permanent well casings shall be surrounded by a minimum of 1½ inches of grout to the depth required by the department**.** Grouting consists of filling the annular space between the permanent casing and the drill hole with impervious material. Grouting is necessary to protect water-bearing aquifers from contamination, to prevent unwanted water movement between aquifers and to preserve or protect the hydraulic response of the water producing zones**.**

b. Grout materials shall consist of Portland cement conforming to the latest AWWA Standard and water, with not more than six gallons of water per sack (94 pounds**)** of cement

c. Additives may be used to increase fluidity of grout materials or to bridge voids, subject to prior approval by the department.

d. Application.

    1. Sufficient annular opening shall be provided to permit a minimum of 1 1/2 inches of grout around permanent casings, including couplings.
    2. Prior to grouting through creviced or fractured formations, bentonite or similar materials may be added to the annular opening, in the manner indicated for grouting.
    3. Before placing the grout, water or other drilling fluid shall

be circulated in the annular space sufficient to clear obstructions.

4. When grouting a well, one of the following methods shall be used:
    1. The Positive-Placement Interior Method: When the annular opening is less than three inches (the diameter of the drill hole is less than six inches larger than the casing diameter), grout shall be installed using the positive-placement interior method. This method involves introducing the grout through the well casing or a pipe inside the well casing. Either an expandable or drillable plug shall be installed at the bottom of the well casing and the grout pipe shall extend through this plug. Then grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled. If the grout does not reach the surface, the driller shall wait at least 24 hours and then determine the elevation of the top of the grout. The appropriate Department of Natural Resources Regional Office shall be contacted for approval of the method used to complete grouting of the well by using the tremie method;
    2. The Positive-Placement Exterior Method: When the annular opening is three or more inches (the diameter of the drill hole is six inches or more larger than the casing diameter) and less than 300 feet in depth, grout may be placed by the positive-placement exterior method. This method requires pumping grout through a grout pipe installed in the annular opening. The maximum diameter of the grout pipe shall be at least 1½-inches smaller than the annular opening. The grout shall be placed to the bottom of the annular opening in one continuous operation until the annular opening is filled. The grout pipe shall be raised as the grout is placed but the discharge end of the grout pipe must be submerged in the placement grout at all times until grouting is complete. The grout pipe shall be maintained full, to the surface, at all times until grouting is complete. In case of interruption of grouting operations, the grout pipe must be removed from the drill hole and all air and water displaced from the grout pipe and the pipe flushed clean with clear water. After the grout pipe is cleaned, it may be placed in the drill hole and grouting resumed; or
    3. The Tremie Method: When the annular opening is four

or more inches (the diameter of the drill hole is eight inches or more larger than the casing diameter) and less than 100 feet in depth, grout may be placed by gravity through a tremie pipe. The tremie pipe shall be installed to the bottom of the annular opening and the grout placed in one continuous operation until the annular opening is filled. The tremie pipe shall be raised as the grout is placed but the discharge end of the pipe must be submerged in the placement grout at all times until grouting is complete. The tremie pipe shall be maintained full, to the surface, at all times until grouting is complete. The maximum diameter of the tremie pipe shall be at least 1½-inches smaller than the annular opening.

5. After grouting is applied, work on the well shall be discontinued for at least 72 hours or until the grout has set properly.

e. Guides.

1. The casing must be provided with sufficient guides welded to the casing to permit unobstructed flow and uniform thickness of grout.
2. Spacer guides shall be provided at the bottom, at the top, and along the entire length of the casing at 100 foot intervals.

3.2.5.12. Upper terminal well construction.

a. Permanent casing for all groundwater sources shall project at least 12 inches above the pumphouse floor or concrete apron surface and at least 18 inches above final ground surface.

b. Where a vertical turbine pump is provided for the well, the pumphouse must have forced ventilation of at least six changes of air per hour.

c. The top of the well casing at sites subject to flooding shall terminate at least four feet above the 100 year level or the highest known flood elevation, whichever is higher, or as the department directs.

3.2.5.13. Development.

a. Practically all drilling methods cause compaction of unconsolidated materials in an annulus of variable thickness about a drill hole. In consolidated formations, similar compaction may occur in some poorly cemented rocks. In addition, fines are driven into the wall of the hole, drilling mud invasion may occur, and a mud cake may form on the wall of a hole. Proper well development breaks down the compacted drill hole wall, liquefies jelled mud, and draws it and fines into the well where they can be

removed. Therefore, every well should be developed and the well construction specifications should include the well development methods to be used.

b. Every well drilled into an unconsolidated formation shall be developed by surging and bailing or surging and pumping. The surging shall be done using a single or double solid or valved surge block. Surging shall start at the lowest screen in the well and proceed upwards. Pumping shall be done through the surge block by incorporating suction pipe in the fabrication of the block and shall be done simultaneously with surging. Other methods of development may be considered on a case by case basis and must be specifically approved by the department before use.

c. The approval of the department is required before doing any chemical washing of a well with mud dispersing agents, acids or other chemicals.

d. Development shall continue until the maximum specific capacity is obtained from the completed well.

e. The specifications must include a detailed description of the well development methods to be used.

f. Any redevelopment or rehabilitation shall require prior approval from the department.

3.2.5.14. Capping requirements.

a. A continuously welded metal plate or a threaded cap is the preferred method for capping a well. For gravel wall wells that have inner and outer casings, a continuously welded metal plate shall be provided to cap the area between the two casings**.**

b. A properly fitted, firmly driven, solid wooden plug is the minimum acceptable method of temporarily capping a well until pumping equipment is installed.

c. At all times during the progress of work, the contractor shall provide protection to prevent tampering with the well or entrance of foreign materials.

3.2.5.15. Well plugging.

All well plugging shall conform to appropriate standards developed by the Missouri Department of Natural Resources.

3.2.6. Well pumps, discharge piping and appurtenances.

3.2.6.1. Line shaft pumps.

a. Wells equipped with line shaft pumps shall:

1. Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least one-half inch into the pump base; and

2. Have the pump foundation and base designed to prevent water from coming into contact with the joint.

b. Avoid the use of oil lubrication. For existing wells with oil-lubricated pumps and new wells where oil lubrication cannot be avoided, only food grade vegetable oil or mineral oil approved by the ANSI/NSF shall be used.

3.2.6.2. Submersible pumps.

Where a submersible pump is used:

a. The top of the casing shall be effectively sealed against the entrance of water under all conditions, including the vibration or movement of conductors or cables;

b**.** The electric cable from the pump control panel to the well shall be installed in electric conduit and in a manner that it does not create a fall or tripping hazard; and

c. The electrical cable shall be firmly attached to the riser pipe at 20-foot intervals or less.

3.2.6.3. Discharge piping.

a. The discharge piping shall:

1. Be restrained joint or fusion welded pipe;
2. Not be solvent welded plastic or galvanized iron pipe**;**
3. Be designed so that the friction loss will be low;
4. Have the control valves and appurtenances located in a pump house and above the pump house floor when an above-ground discharge is provided;
5. Be protected against the entrance of contamination;
6. Be equipped with a check valve, a shutoff valve, a pressure gauge, a totaling water meter, and a sampling tap located at a point where positive pressure is maintained;
7. Where applicable, be equipped with an air release and vacuum relief valve located upstream from the check valve; with exhaust and relief piping terminating in a down-turned position at least 18 inches above the floor and covered with an 18-mesh corrosion resistant screen;

8 Be valved to permit test pumping and control of each well;

9. Have all exposed piping, valves and appurtenances protected against physical damage and freezing;
10. Be properly anchored to prevent movement and be properly supported to prevent excessive bending forces; and
11. Be protected against surge or water hammer.

b. The discharge piping should be provided with a means of pumping to waste, but shall not be directly connected to a sewer.

3.2.6.4. Pitless well units.

a. The department must be contacted for approval of specific applications of pitless units.

b. Pitless units shall:
   1. Be shop-fabricated from the point of connection with the well casing to the unit cap or cover;
   2. Be threaded or welded to the well casing;
   3. Be of watertight construction throughout;
   4. Be of materials and weight at least equivalent and compatible to the casing;
   5. Have field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection; and
   6. Terminate at least 18 inches above final ground elevation, four feet above the 100-year flood level, or the highest known flood elevation whichever is higher.

c. The design of the pitless unit shall make provision for:
   1. Access to disinfect the well;
   2. A properly constructed casing vent meeting the requirements of this document;
   3. Facilities to measure water levels in the well as specified in this document;
   4. A sanitary well seal at the upper terminal of the unit;
   5. A contamination-proof entrance connection for electrical cable;
   6. An inside diameter as great as that of the well casing; up to and including casing diameters of 12 inches in order to facilitate work and repair on the well, pump or well screen; and
   7. At least one check valve within the well casing or in compliance with requirements of the department.

d. If the connection to the casing is to be welded in the field, shop-assembled unit must be designed specifically for field welding to the casing. The only field welding permitted will be that needed to connect a pitless unit to the casing.

3.2.6.5. Casing vent.

Provisions shall be made for venting to the atmosphere the well casing that houses the well pump. The vent pipe shall be installed into the side of the casing and shall terminate in a downturned position at or above the top of the casing or pitless unit with the opening covered with a 18 mesh, corrosion resistant screen. The pipe connecting the casing to the vent shall be of adequate size to provide rapid venting of the casing but shall not be smaller than 1.5-inches in diameter.

3.2.6.6. Water level measurement.

a. Provisions shall be made for periodic measurement of water levels in the completed wells,

b. Where pneumatic lines are used, water level measuring equipment and accessories shall be provided using corrosion-resistant materials attached firmly to the drop pipe or pump column in such a manner as to prevent entrance of foreign materials.

3.2.6.7. Observation wells.

If they are to remain in service after completion of a water supply well, observation wells shall be constructed in accordance with the requirements for permanent wells and protected at the upper terminal to preclude entrance of foreign materials.

Figure 3 - Steel Pipe

STEEL PIPE					
SIZE (inches)	**DIAMETER (inches)**		**WALL THICKNESS (inches)**	**WEIGHT (pounds/feet)**	
	Outside	**Inside**		**plain ends (calculated)**	**threads & couplings (nominal)**
6 id.	6.625	6.065	0.280	18.97	19.18
8	8.625	7.981	0.322	28.55	29.35
10	10.750	10.020	0.365	40.48	41.85
12	12.750	12.000	0.375	49.56	51.15
14 od.	14.000	13.250	0.375	54.57	57.00
16	16.000	15.250	0.375	62.58	
18	18.000	17.250	0.375	70.59	
20	20.000	19.250	0.375	78.60	
22	22.000	21.000	0.500	114.81	
24	24.000	23.000	0.500	125.49	
26	26.000	25.000	0.500	136.17	
28	28.000	27.000	0.500	146.85	
30	30.000	29.000	0.500	157.53	
32	32.000	31.000	0.500	168.21	
34	34.000	33.000	0.500	178.89	
36	36.000	35.000	0.500	189.57	

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Chapter 4 -- Treatment

4.0. General.

The design of treatment processes and devices shall depend on evaluation of the nature and quality of the particular water to be treated and the desired quality of the finished water.

4.1. Clarification.

Plants using conventional clarification to treat water prior to filtration shall be designed to:

a. Provide at least a two-stage treatment process consisting of primary rapid mixing, flocculation and sedimentation and secondary rapid mixing, flocculation, and sedimentation, in series, to treat surface water;
b. Provide at least a single stage treatment consisting of rapid mix-flocculation-sedimentation for clarification to treat groundwater under the direct influence of surface water**;**
c. Be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time;
d. Have walls and interior equipment constructed of stainless steel or non-metallic materials or provide duplicate parallel units;
e. Avoid constructing conventional cylindrical settling units because of their excessive short-circuiting and poor flow characteristics;
f. Be started manually following shutdown, unless otherwise approved by the department where automatic monitoring control is provided;
g. Be constructed to minimize hydraulic head losses between units to allow future changes in processes without the need for repumping; and
h. Be piped so raw water cannot be discharged directly into the filters.

4.1.1. Presedimentation, or raw water storage basins.

a. Presedimentation basin is recommended for water systems taking water from navigational rivers.
b. Storage Capacity. Presedimentation basins should be sized so that the river intake can be shut down to allow spill and/or contamination to pass before resuming normal operation**.**
c. Inlet. Incoming water shall be dispersed across the full width of the line of travel as quickly as possible; short-circuiting must be prevented.
d. Bypass. Provisions for bypassing presedimentation basins shall be included.

4.1.2. Rapid Mix.

a. Rapid mix shall mean the rapid dispersion of chemicals throughout the water to be treated, by violent agitation. The engineer shall submit the design basis for the velocity gradient (G-value) selected, taking into consideration the chemicals to be added, water temperature, color, and other water related water quality parameters. Interference between treatment chemicals and the optimum locations and sequences for feeding different chemicals shall be considered in rapid mix design. Multiple rapid mix or chemical injection points may be necessary.

b. Equipment. Basins should be equipped with mechanical mixing devices**.** Static mixing may be considered if the treatment flow is not variable and can be justified by design engineer.

c. Mixing. The detention period shall not be more than 30 seconds at the maximum design flow rate.

d. Location. The rapid mix and flocculation basins shall be as close together as possible. The connecting piping between them shall be designed to prevent chemical buildup.

4.1.3. Flocculation.

a. Flocculation is a process to enhance the collection of smaller floc particles into larger, more easily settleable particles through gentle stirring by hydraulic or mechanical means**.**

b. Basin Design. Inlet and outlet design shall prevent short-circuiting and destruction of floc. A drain and/or pumps shall be provided to handle dewatering and residual removal. Outlets interconnecting the flocculation and sedimentation basins at the bottom must be valved.

c. Detention. The detention time for floc formation shall be at least 30 minutes. The department may consider reduced detention time for ballasted flocculation or for tapered flocculation with diminishing velocity gradient if justified by the engineer.

d. Flow velocity. The velocity of flow through the flocculation basin shall not be less than 0.5 feet per minute nor greater than 1.5 feet per minute.

e. Equipment. Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 3.0 feet per second. Turbine, radial flow type impellers should not be used for flocculation because of their high shear rates. When agitators with axial flow and hydrofoil impellers are used, the designing engineer shall specify the desired velocity gradient (G) range, impeller tip speed, ratio of impeller diameter to equivalent tank diameter and superficial velocity range. The impeller tip speed should not exceed 8 ft/sec for a three or four-blade hydrofoil. The superficial velocity should not be less than 3 ft/min nor greater than 10 ft/min. The ratio of the impeller diameter to equivalent tank diameter should not be less than 0.30 nor larger than 0.45.

f. Piping. Flocculation and sedimentation basins shall be as close together as possible. The velocity of flocculated water through pipes or conduits to

settling basins shall be not less than 0.5 feet per second nor greater than 1.5 feet per second. Allowances must be made to minimize turbulence at bends and changes in direction.

g. Other designs. Baffling may be used to provide for flocculation in small plants only after consultation with the department. The design should be such that the velocities and flows noted above will be maintained.

h. Superstructure. A superstructure over the flocculation basins may be required.

4.1.4. Sedimentation.

Sedimentation, a process for removal of solids before filtration by gravity separation, shall follow flocculation. The detention time for effective clarification is dependent upon a number of factors related to basin design and the nature of the raw water. The following criteria apply to conventional sedimentation units:

a. Conventional rectangular settling units shall have a minimum length to width ratio of three to one (3:1) or shall have baffles that will provide a flow path that gives the same ratio;

b. Detention Time. Settling units shall provide a minimum of four hours of settling time. This may be reduced to two hours for lime-soda softening facilities treating only groundwater. The volume that will be used in determining the detention time shall be calculated using the effective dimensions of the basin. The effective length is measured from the inside edge of the last influent weir or launder to the inside edge of the first effluent weir or launder. The effective side water depth is measured from the effluent level of the launders or submerged orifices to the bottom of the basin. The volume above the submerged orifices should not be included when calculating for the detention time. Where a mechanical residuals scraper is not provided and residual storage volume is allocated at the bottom of the basin, the effective side water depth shall be measured above the allocated residual storage. Reduced sedimentation time may be approved when equivalent effective settling is demonstrated;

c. Inlet Devices. Inlets shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows across the basin;

d. Outlet Devices. Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:

    1. The rate of flow over the weirs shall not exceed 20,000 gallons per day per foot of the outlet launder;

2. Submerged orifices shall be designed to provide an even flow across the launder to prevent excessive water velocities and to minimize headloss;
3. Submerged orifice launders should not be located lower than three feet below the water surface; and
4. The entrance velocity through the submerged orifices shall not exceed 0.5 feet per second.

e. Depth of Basin. A minimum side water depth of ten feet must be provided. Where mechanical residuals removal is not provided, additional depth of basin shall be required for residuals storage.

f. Velocity. The velocity through settling basins shall not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Fixed or adjustable baffles must be provided as necessary to achieve the maximum potential for clarification.

g. Overflow. An overflow weir or pipe designed to establish the maximum water level on top of the filters should be provided. The overflow shall discharge by gravity with a free fall at a location where the discharge will be noted.

h. Superstructure. A superstructure over the sedimentation basins may be required particularly for water systems that may have problems controlling disinfection byproducts. A cover may be provided in lieu of a superstructure if:

1. Provisions are included for adequate monitoring under all weather conditions;
2. There is no mechanical equipment in the basin; and
3. The basin is equipped with a mechanical sludge removal, large access ways shall be provided for maintenance. The access ways shall be sized and located to provide safe ventilation during basin maintenance and allow easy removal and replacement of the mechanical residuals removal equipment.

i. Residuals Collection. Mechanical residuals collection equipment should be provided.

j. Drainage. Basins must be provided with a means for dewatering. Basin bottoms should slope toward the drain not less than one foot in 12 feet where mechanical residuals collection equipment is not required.

k. Flushing Lines. Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the department.

l. Safety. Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guardrails should be included. Compliance with other applicable safety requirements, such as OSHA, should be considered.

m. Residuals Removal. Residuals removal design:

1. Shall have a minimum of three inches in diameter residuals pipes arranged to facilitate cleaning;
2. Shall prevent clogging particularly at the entrance to residuals withdrawal piping;

3. Shall have valves located outside the tank for accessibility; and
4. Should include provisions for the operator to observe and sample residuals being withdrawn from the unit.

n. Residuals Management. Facilities for residuals handling and disposal shall be reviewed and approved by the Water Pollution Control Program of this department. The required NPDES (National Pollutants Discharge Elimination System) permit(s) must be obtained before constructing or operating the residuals facilities.

4.1.5. Solids Contact Unit.

Units are normally acceptable for combined softening and clarification where water characteristics are not rapidly variable, flow rates are uniform, and operation is continuous. Before considering solids contact as clarifiers without softening, specific approval of the department shall be obtained based on records of turbidity fluctuations, color, temperature, alkalinity, and hardness. Solids contact units may be considered only as primary clarifiers. Clarifiers should be designed for the maximum uniform rate and should be adjustable to changes in flows that are less than the design rate due to changes in water characteristics. Secondary stage treatment by conventional methods must be provided for surface waters. For a single stage treatment, a minimum of two solids contact units in parallel shall be provided or the unit and all its interior equipment shall be made of stainless steel or non-metallic materials.

4.1.5.1. Installation.

Supervision by a representative of the manufacturer shall be provided with regard to all mechanical equipment at the time of installation and initial operation.

4.1.5.2. Operation.

Adequate piping with suitable sampling taps strategically located to permit the collection of water samples and sludge from critical portions of the units shall be provided. Sampling taps shall be provided at the sludge withdrawal level and preferably at every two feet interval from the basin bottom to two feet below the effluent level. The location of the sampling taps shall allow safe and easy access for routine sampling and be provided with facilities for easy cleanup. Before the units are placed in service**,** the following shall be provided for proper operation:

a. A comprehensive operating manual for the unit and its equipment including “as-built” detailed drawings of the unit, equipment and accessories;
b. Training of operating personnel**;**
c. A complete outfit of tools and accessories; and
d. Necessary laboratory equipment.

4.1.5.3. Chemical feed.

a. Chemicals shall be applied at such points and by such means as to ensure satisfactory mixing of the chemicals with the water. Interference between treatment chemicals and optimum locations and sequences for feeding different chemicals shall be considered. Multiple rapid-mixing facilities or chemical injection points may be necessary.

b. Cross-connection control must be provided for the make-up water lines of each chemical**.**

c. All chemicals shall meet AWWA Standards and must be certified for drinking water use under ANSI/NSF Standards 60/61.

4.1.5.4. Rapid mixing.

To ensure proper mixing of applied chemicals, a rapid mixing device or a chamber ahead of solids contact units shall be required for units treating surface water and may be required for units treating other waters. Mixing devices employed shall be constructed to:

a. Provide good mixing of the raw water with previously formed residuals particles; and

b. Prevent deposition of solids in the mixing zone.

4.1.5.5. Flocculation.

Flocculation equipment shall:

a. Be adjustable in speed and/or pitch over a range consistent with the type of raw water being treated and the residuals being developed;

b. Provide for coagulation in a separate chamber or baffled zone within the unit; and

c. Provide at least 30 minutes of flocculation and mixing time.

4.1.5.6. Residuals concentrators.

a. The equipment should provide either internal or external concentrators in order to obtain a concentrated residuals with a minimum of waste water.

b. Large basins should have at least two sumps for collecting residuals with one sump located in the central flocculation zone.

4.1.5.7. Residuals removal.

The residuals removal design shall:

a. Have a minimum of three inches in diameter residuals pipes so arranged to facilitate cleaning;

b. Prevent clogging at the entrance to residuals withdrawal piping;

c. Have valves located outside the tank for accessibility; and

d. Be automatic**.** Timers on automatic valves shall be designed to allow frequency and duration intervals to be set to provide frequent operation for very short intervals. Operation of automatic valves shall provide for fast opening and closing that will be compatible with the required short intervals residuals removal, shall discharge into a facility that is approved and permitted by the Water Pollution Control Program of this department, and should include provisions for the operator to observe and sample residuals being withdrawn from the unit.

4.1.5.8. Cross-connections.

a. Blow-off outlets and drains must terminate and discharge at places satisfactory to the department.
b. Cross-connection control must be included for the potable water lines used to backflush residuals lines.

4.1.5.9. Detention period.

The detention time shall be established on the basis of the raw water characteristics and other local conditions that affect the operation of the unit. Based on design flow rates, the detention time should be:

a. Two and one-half to four hours for suspended solids contact softeners treating surface water; and
b. One and one-half to two hours for the suspended solids contact softeners treating only ground water.

4.1.5.10. Suspended slurry concentrate.

Softening units should be designed so that continuous slurry concentrates of one percent (1%) or more, by weight, can be satisfactorily maintained. In general, softening efficiency improves as suspended slurry concentration increases, although with very high slurry concentration, carry-over is a problem.

4.1.5.11. Water losses.

a. Units shall be provided with suitable controls for residuals withdrawal.
b. The total water losses should not exceed:
    1. Five percent for clarifiers; or
    2. Three percent for softening units.
c. Solids concentration of residuals bled to waste should be--
    1. Three percent by weight for clarifiers; or
    2. Five percent by weight for softeners.

4.1.5.12. Weirs or orifices.

a. The units should be equipped with either overflow weirs or orifices constructed so that water does not travel more than ten feet horizontally to the collection trough.

b. Weirs shall be adjustable, and at least equivalent in length to the perimeter of the tank. However, peripheral weirs are not acceptable as they tend to cause excessive short-circuiting.

c. Weir loading shall not exceed:
   1. Ten gallons per minute per foot of weir length for units used for clarifiers; or
   2. Twenty gallons per minute per foot of weir length for units used for softeners.

d. Where orifices are used, the loading rates per foot of launder should be equivalent to weir loading rates and shall produce uniform rising rates over the entire area of the tank.

e. Weirs and orifices should be at least two feet from the tank wall to minimize carry-over.

4.1.5.13. Upflow rates.

a. The upflow rates shall be determined at the residuals separation line, approximately four feet below the collection weirs or orifices**.**

b. Unless supporting data is submitted to justify higher rates, the upflow rates shall not exceed:
   1. Seventy-five hundredths (0.75) gallon per minute per square foot for units used for clarifiers, or
   2. One (1.0) gallon per minute per square foot for units used for softening.

4.1.6. Tube or plate settlers.

A proposal for settler unit clarification must include pilot plant and/or full-scale demonstration data on water with similar quality prior to the preparation of final plans and specifications for approval. Settler units consisting of variously shaped tubes or plates may be installed in multiple layers at an angle to the flow in the sedimentation basin to enhance settling of solids.

4.1.6.1. General Criteria.

a. Inlet and outlet considerations – The design shall maintain velocities suitable for settling in the basin and minimize short-circuiting.

b. Drainage – Drain piping from the basin must be sized to facilitate a quick flush of the of the settler units and to prevent flooding of

the portions of the plant. Basins should have hopper bottom and residuals removal equipment.

c. Protection from freezing – Outdoor installation must provide sufficient freeboard above the top of the settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.
d. Application rate for tubes – A maximum rate of 2-gpm/square foot of cross-sectional area for tube settlers unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.
e. Application rate for plates – A maximum loading rate of 0.5 gpm/ square foot for plate settlers, based on 80 percent of the projected horizontal plate area.
f. Flushing lines – Flushing lines shall be provided to facilitate maintenance and must be properly protected against backflow or back siphonage.

4.2. Filtration.

Filtration is a process for removing particulate matter from water by passing through porous media. Pretreatment shall be required prior to filtration unless otherwise approved by the department. Acceptable filters shall include the following types: rapid rate gravity filters, rapid rate pressure filters, and membrane filters. Other types of filters maybe considered if justified by the engineer through pilot or full-scale testing. The application of these types of filters must be supported by water quality data representing a reasonable period of time to characterize variations in water quality.

4.2.1. Rapid rate gravity filters.

4.2.1.1. Rate of filtration.

The design rate shall be a maximum of two gallons per minute per square foot of the filter surface area. Higher rates may be considered based on raw water quality, degree of pretreatment provided, type of filter media, water quality control parameters, competency of operating personnel, and other factors as required by the department. In any case, the filter rate must be proposed and justified by the designing engineer to the satisfaction of the department prior to the preparation of final plans and specifications.

4.2.1.2. Number.

At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of

meeting the plant design capacity at the approved filtration rate with one filter removed from service. Provisions to control the flow into or from each filter and to divide flows equally between each active filter must be provided.

4.2.1.3. Structural details and hydraulics.

The filter structure shall be designed to provide for:

a. Vertical walls within the filter;
b. No protrusion of the filter walls into the filter media;
c. Cover by superstructure (roof drains must not discharge into the filters);
d. Head room to permit normal inspection and operation;
e. Minimum depth of filter box of 8½ feet;
f. Minimum water depth over the surface of the filter media of three feet;
g. Trapped effluent to prevent backflow of air to the bottom of the filters;
h. Prevention of floor drainage to the filter with a minimum four-inch curb around the filters;
i. Prevention of flooding by providing overflow;
j. Maximum velocity of treated water in pipe and conduits to filters of two feet per second;
k. Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy, or following lime-soda softening;
l. Washwater drain capacity to carry maximum flow;
m. Walkways around filters, to be not less than 24 inches wide;
n. Safety handrails or walls around all filter walkways;
o. Construction to prevent cross connections and common walls between potable and nonpotable water; and
p. Provisions for filtering to waste at normal filtration rates until the turbidity of the filter effluent drops to an acceptable level. An air gap or other backflow prevention assembly shall be provided at the filter-to-waste line. Controls for filtering to waste should be incorporated with the other filter controls.

4.2.1.4. Washwater troughs.

Washwater troughs shall be designed to have:

a. The bottom of the troughs above the maximum level of expanded media during washing;
b. The troughs carry the maximum rate of washwater with a two-inch freeboard;
c. The top edge of the troughs level and all at the same elevation;
d. The troughs spaced so that each trough serves the same number of square feet of filter area; and
e. The maximum horizontal travel of suspended particles to reach the trough not to exceed three feet.

4.2.1.5. Filter material.

a. All filter materials shall meet the current AWWA standards for filtering materials. The media shall be clean silica sand or other natural or synthetic media approved by the department, having the following characteristics:
    1. A total depth of not less than 24 inches and generally not more than 30 inches;
    2. A minimum of 12 inches of media having an effective size range no greater than 0.45 mm to 0.55 mm, and specific gravity greater than other filtering materials within the filter; and
    3. A uniformity coefficient of the smallest material not greater than 1.65.

b. Types of filter media.
    1. Anthracite - Clean crushed anthracite, or a combination of anthracite and other media may be considered on the basis of experimental data specific to the project, and shall have:
        1. Effective size of 0.45 mm - 0.55 mm with uniformity coefficient not greater than 1.65 when used alone,
        2. Effective size of 0.6 mm – 0.8 mm with a uniformity coefficient not greater than 1.85 when used as a cap; and
        3. As an exception, effective size for anthracite used alone on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies).
    2. Sand. Filter sand shall have an effective size of 0.45 mm to 0.55 mm and a uniformity coefficient of not greater than 1.65.
    3. Granular Activated Carbon (GAC) – Granular activated carbon as a single media may be considered for filtration only after pilot or full-scale testing. The design shall include the following:
        1. The media must meet the basic specifications for filter media in this section. Larger size may be allowed where pilot or full-scale tests have demonstrated that treatment goals can be met under all conditions;
        2. There must be provisions for a chlorine residual and adequate contact time in the water following filters and prior to distribution;
        3. There must be means for periodic treatment of filter material for control of bacterial and other growth; and
        4. Provisions must be made for frequent replacement or regeneration.
    4. Other filter media – Other media will be considered based on experimental data and operating experience.

c. Torpedo sand - A three-inch layer of torpedo sand shall be used as a supporting media for filter media, and should have:
    1. Effective size of 0.8 mm to 2.0 mm; and

2. Uniformity coefficient not greater than 1.7.

d. Gravel.

1. Gravel, when used as the supporting media shall consist of cleaned and washed hard, durable, rounded silica particles and shall not include flat or elongated particles. The minimum thickness of each gravel layer shall not be less than twice the size of the biggest possible particle. The coarsest gravel shall be 2 1/2 inches in size when the gravel rests directly on a lateral system, and must extend above the top of the perforated laterals. A minimum of four layers of gravel shall be provided in accordance with the following size and depth distribution:

Size	**Depth**
2 1/2 to 1 1/2 inches	5 to 8 inches
1 1/2 to 3/4 inches	3 to 5 inches
3/4 to 1/2 inches	3 to 5 inches
1/2 to 3/16 inches	2 to 3 inches
3/16 to 3/32 inches	2 to 3 inches

2. Reduction of gravel depths, number of layers and size gradations may be considered upon justification to the department by showing conformance to AWWA standards when proprietary filter bottoms are specified.

4.2.1.6. Filter bottoms and strainer systems.

Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used where iron or manganese or hardness precipitation may clog them or with waters softened by lime. The manifold-type collection systems shall be designed to:

a. Minimize loss of head in the manifold and laterals;

b. Ensure an even distribution of washwater and an even rate of filtration over the entire area of the filter,

c. Provide the ratio for the area of the final openings of the strainer systems to the area of the filter at about 0.003,

d. Provide the total cross-sectional area of the laterals at about twice the total area of the final openings,

e. Provide the cross-sectional area of the manifold at 1½ to 2 times the total area of the laterals;

f. Provide spacing of the laterals not to exceed 12 inches; and

g. Provide spacing of the perforations along the lateral not to exceed eight inches.

4.2.1.7. Surface wash or subsurface wash.

Surface wash facilities are required except for pressure filters or where air scour is used. A 1½ -inch to 2-inch pressure line must be located

conveniently on the filter plant operating floor and equipped with suitable lengths of 1-inch to 1½-inch pressure hose and nozzle. A suitable rack should be available for storing the hose. Auxiliary surface or subsurface wash may be accomplished by a system of fixed nozzles or a revolving type apparatus. All devices shall be designed with:

a. Provisions for water pressures of at least 45 psi;
b. A properly installed backflow prevention assembly to prevent back siphonage if connected to the treated water system; and
c. Rate of flow of 2.0 gallons per minute per square foot of filter area with fixed nozzles or 0.5 gallons per minute per square foot with revolving arms.

4.2.1.8. Air Scouring.

Air scouring may be considered in place of surface wash based on the following standards:

a. Air scouring controls must allow the operator to control the air and water flow rates and duration. Rate of flow indicators for air and water shall be provided. Provide manual over-ride to the automated backwash controls for backwashing the filters including air scour. Automated backwash controls shall not automatically start filter backwash. Filter backwashing must be initiated manually;
b. Air flow for air scouring the filter must be three to five cubic feet per minute per square foot of filter area when the air is introduced in the underdrain; a lower air rate shall be used when the air scour distribution system is placed above the underdrains;
c. A method for avoiding excessive loss of the filter media during backwashing must be provided;
d. Air scouring should be followed by a fluidization wash to restratify the media;
e. Air must be free from contamination;
f. Air scour distribution system should be placed at or below the media and supporting bed interface; if placed at the interface, the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system;
g. Piping for the air distribution system shall not be flexible hose which may collapse when not under pressure and shall not be relatively soft material which may erode at the orifice opening with the passage of air at high velocity;
h. Air delivery piping shall not pass down through the filter media unless a minimum of two anti-seepage collars, six inches apart are provided in each pipe. The anti-seepage collars shall extend three inches out from the pipe and be continuous around the entire circumference of the pipe. No arrangement in the filter design shall allow short circuiting between the applied unfiltered water and the filtered water;
i. Consideration should be given to maintenance and replacement of air line;

j. During air scour, the backwash water rate must be variable and should not exceed eight gallons per minute per square foot unless operating experience shows that higher rate is necessary to remove scoured particles from the filter media surfaces;
k. The filter underdrain shall be designed to accommodate air scour piping when the piping is installed in the underdrain; and
l. Subparagraph 4.2.1.10 must be followed when backwashing filters.

4.2.1.9. Appurtenances.

a. The following shall be provided for every filter:
   1. Influent and effluent sampling points;
   2. An indicating, and preferably recording, loss of head gauge or transmitter;
   3. An indicating rate-of-flow meter. A rate controller that limits the rate of filtration to a maximum rate through each filter may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a control valve or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the department;
   4. Influent or effluent controls that distribute plant flows evenly between the filters and limit the flow rate to the maximum allowable rate; and
   5. Provisions for filtering to waste, especially when used in surface water, with appropriate measures for backflow prevention.
b. It is recommended the following be provided for every filter:
   1. A continuous turbidity monitoring and recording device for surface water treatment and lime softening plants to monitor filter to waste and filter effluent turbidity,
   2. Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing.
   3. A minimum 1½ inch pressure hose equipped with shut-off nozzles or valve and storage rack at the operating floor for washing filter walls; and
   4. Turbidity and/or particle monitoring equipment as a means to enhance treatment operation when treating surface waters.
c. When the top of the filter walls are below the pretreatment basin overflow, the filter basins must be provided with overflow piping.

4.2.1.10. Backwash.

Provisions shall be made for washing filters as follows:

a. A minimum backwashing rate of 15 gallons per minute per square foot, consistent with water temperatures and specific gravity of the filter media shall be provided. A rate of 20 gallons per minute per

square foot or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended. A reduced rate of 10 gallons per minute per square foot may be acceptable for full depth anthracite or granular activated carbon filter media;

b. Filtered water provided at the required rate by washwater tanks, a washwater pump, from the high service main, or a combination of these;
c. Washwater pumps in duplicate unless an alternate means of obtaining washwater is available and if air scouring is provided, duplicate air compressors/blowers except where water flow is adequate to backwash the filters at the required rates with water alone;
d. Not less than 15 minutes wash of one filter at the design rate of wash;
e. Timer to record total backwash time;
f. A washwater regulator or valve on the main washwater line to obtain the desired rate of filter wash with the washwater valves on the individual filters open wide;
g. A totaling rate-of-flow on the main washwater line, with an indicator so that it can be easily read by the operator during the washing process; and
h. Equipment designed to prevent rapid changes in backwash water flow.

4.2.2. Rapid rate pressure filters.

4.2.2.1. General.

a. The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of surface water or groundwater under the direct influence of surface water or following a lime-soda softening process.
b. The minimum requirements regarding number, rate of filtration, structural details and hydraulics, filter media, etc., for rapid rate gravity filters (subsection 4.2.1.) also applies to pressure filters, where appropriate.

4.2.2.2. Rate of filtration.

The rate of filtration shall not exceed three gallons per minute per square foot of the filter area. Higher rates may be considered based on satisfactory results of pilot or full-scale testing. The filter piping must be arranged as simple as possible to provide for filtration, backwashing and filtering to waste of each filter individually.

4.2.2.3. Details of design.

The filters shall be designed to provide for:

a. Loss of head gauges on the inlet and outlet pipes of each filter;

b. An easily readable meter or flow indicator on each battery of filters. A flow indicator is recommended for each filtering unit where the filter influent or effluent automatically distributes the flow evenly between active filters;
c. Minimum side wall shell height of six feet. A corresponding reduction in sidewall height is acceptable where proprietary bottoms permit reduction of the gravel depth;
d. The top of the washwater collectors to be at least 18 inches above the surface of the media;
e. The underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 20 gallons per minute per square foot of filter area;
f. Backwash flow indicators and controls that are easily readable while operating the control valves for filter effluent piping that exits the filter below the top of the underdrain. Filter effluent piping shall not extend above the underdrain inside the filter;
g. An air release valve on the highest point of each filter;
h. At least a 24-inch diameter accessible manhole to facilitate inspection, repairs and removal of filter media for filters 36 inches or more in diameter. Sufficient manholes shall be provided for filters less than 36 inches in diameter**;**
i. Means to observe the wastewater during backwashing; and
j. Construction to prevent cross-connection.

4.3. Membrane Filtration Design.

Four categories of membrane filtration are generally recognized. They are microfiltration, ultrafiltration, nanofiltration and reverse osmosis. One can find a number of definitions for these categories but for the purposes of this design standard they are set strictly by membrane pore size and are as follows. Microfiltration covers a pore size range of 0.1 to 2.0 microns. Ultrafiltration covers a pore size range of 0.01 to 0.1 microns. Nanofiltration covers a pore size range of 0.001 to 0.01 microns. Reverse Osmosis covers a pore size range of 0.0001 to 0.001 microns. Using these definitions means that microfiltration does not remove microbiological contaminants and that only nanofiltration and reverse osmosis provide virus removal.

4.3.1. Membrane filtration performance.

Membrane filtration performance is highly site specific. Therefore, pilot studies shall be done to assure that an acceptable quality finished water will be produced through all the source water seasonal quality variations. The selection of membrane treatment shall be determined by source water quality characteristics, treated water quality requirements, the targeted materials to be removed, membrane pore size, molecular weight cutoff, membrane materials and system treatment configuration. All membranes must be certified by the National Sanitation Foundation International. (NSF) to contain no leachable surfactants or other chemicals. When membrane

filtration is proposed for removal of microbial contaminants, the membrane used must be certified by the NSF to remove the contaminants expected.

4.3.2. Membrane Filtration.

Pretreatment is required for all types of membrane filtration, to assure removal of color, tastes and odors, to control membrane fouling and to assure useful membrane lives. The type of pretreatment required depends on the characteristics of the source water and the type of membrane filtration selected.

4.3.2.1. Source water testing.

Extensive testing of the source water for all parameters that may affect membrane filtration and finished water quality shall be done.

4.3.2.2. Seasonal source water variation.

Since the source water quality may vary seasonally, sampling shall cover at least one full year.

4.3.2.3. Water quality extremes.

Historic information shall be reviewed to determine water quality extremes that may be expected.

4.3.2.4. Test results.

Tabulated results of tests done and summaries and conclusions shall be submitted as a part of the engineering report proposing membrane filtration.

4.3.3. Design Flux.

Design flux is the volume of water that can move through a given area of membrane in a given time, usually measured in gallons per square foot per day (gfd). The type of membrane material, the characteristics of the raw water, operating pressures, degree of pretreatment, the style of membrane, etc., determine design flux. Information on each of these parameters shall be provided in submittals to the department. Reverse osmosis design should provide for a flux of at least 15 gfd. Microfiltration design fluxes average around 70 gfd. Nanofiltration and ultrafiltration design fluxes fall proportionally in-between. The flux used to design a specific installation depends on the purpose of the installation and the degree of system integrity required. The greater the number of membrane fibers required to produce a given output of water the smaller the impact of bypass flow from a single break. Thus, for removal of microbial contaminants, lower than average design fluxes should be used. Justification for the design flux used shall be provided in the submittal to the department.

4.3.4. Design Pressure Drop or Transmembrane Pressure.

Design pressure drop or transmembrane pressure is the pressure differential range required across the membrane to produce at the design flux for a normal filter run. Large pressure differentials require high influent pressures, increase operating costs, and shorten membrane life. Also, bypass flow from membrane fiber breakage is proportional to the pressure differential across the membrane. Pretreatment and membrane selection shall be done to provide the lowest practical design pressure drop.

4.3.5. Membrane Fouling.

Fouling and scaling characteristics of the source water and design cleaning frequency shall be considered. Design shall include provisions for minimizing membrane fouling.

4.3.5.1. System integrity.

System integrity and reliability shall be considered in the design. Multiple membrane arrays, skids or trains shall be provided. The treatment system shall be able to meet design maximum design flows while one membrane array, skid or train is isolated for membrane replacement, testing, back washing or cleaning.

4.3.5.2. Membrane design.

Design shall include piping, valves, fittings and other provisions for isolation and easy removal of membrane arrays, skids or trains and of individual membrane modules for replacement, testing, backwashing and cleaning.

4.3.5.3. Direct testing equipment.

Equipment for direct testing shall be provided to monitor membrane integrity and to detect and locate defects or breaches that could allow feed water to bypass membrane filtration. Direct testing equipment shall include but not be limited to equipment for bubble testing and conducting pressure or vacuum hold testing of membrane modules.

4.3.5.4. Membrane backwashing and air filtration.

Provisions for backwashing the membranes shall be provided. Since backwashing is frequent, duplication of equipment is necessary to assure continuous plant operation. If pressure air is used, the air compressors shall not impart oil into the compressed air. Furthermore, air filtration shall be provided to assure that the membranes are not contaminated with airborne pathogens.

4.3.5.5. Chemical cleaning.

Equipment and appurtenances necessary for chemical cleaning of the membranes shall be provided.

4.3.6. Membrane Rating.

Membranes rated by pore size can be either nominal or absolute. Nominally rated membranes must be rated at the size on their particle retention curve where the membrane retains 98% of that size particles. Absolute rated membranes must retain 100% of particles that are the same size as the pore size rating of the membrane. Specifications shall clearly state whether membrane pore size is nominal or absolute. Nominal size membranes shall be followed by additional treatment.

4.3.7. Recovery.

Recovery is the amount of finished treated water produced from a given amount of feed water. Design percent recovery should be more than 80%.

4.3.8. Membrane Filtration Design.

The following shall be addressed in membrane filtration design:

a. Redundancy of membrane arrays, skids or trains shall be provided sufficient to meet maximum design flow at the highest expected design pressure drops and lowest expected temperatures of the water to be treated.

b. The design shall provide for plugging off and replacing failed membrane fibers. The necessary equipment, valves, piping and appurtenances shall be provided to easily shut off individual membrane modules and to locate and remove defective fibers;

c. The design shall provide for pressure gauges on the influent and effluent piping to each membrane array, skid or train. Preferably these pressures should be measured by pressure transducers with digital read outs and continuous recorders. At a minimum, the gauges shall be 4½-inch diameter, liquid filled, sealed gauges correct to within ½ of 1% of full scale;

d. Online particle sizing and counting equipment shall be provided on the effluent piping of each membrane array, skid or train. Turbidity monitoring equipment shall be provided for on the influent and effluent piping of the membrane arrays, skids or trains. Continuous recording equipment shall be provided for turbidity and for the particle counts in the 2 to 5 micron range. This equipment shall connect with an alarm system to warn operators of excessive particle or turbidity break-through; and

e. Design life of the membranes should be greater than four years.

4.3.9. Flow Meters.

Totaling rate of flow meters shall be provided on the source water influent piping, the plant finished water piping, on membrane backwash piping, on plant water use piping and on cross-circulation or retentate piping.

4.3.10. Post Treatment.

Post treatment shall be provided for neutralization of aggressive water, disinfection with the required contact time, and maintenance of distribution system disinfectant residuals.

4.3.11. Waste Disposal.

Provision shall be made for disposing of chemical cleaning and other wastes generated by membrane filtration for compliance with requirements in 10 CSR 20.

4.4. Disinfection.

Requirements for disinfection and disinfection residuals are found in 10 CSR 60-4.055 Disinfection Requirements. Disinfection by-products are regulated pursuant to 10 CSR 60-4.090. Maximum Contaminant Levels and Monitoring Requirements for Disinfection By-Products.

Chlorine is the preferred disinfecting agent. Disinfection may be accomplished with liquid chlorine, calcium or sodium hypochlorite, chlorine dioxide, or ozone**.** Other disinfecting agents will be considered, provided reliable application equipment is available and testing procedures for a residual are recognized in the latest edition of "Standard Methods for the Examination of Water and Wastewater." Disinfection is required at all surface water supplies and at any ground water supply of questionable sanitary quality or where other treatment is provided. Continuous disinfection is recommended for all water supplies. Disinfection with chloramines is not recommended for primary disinfection to meet the CT requirements in a surface water treatment plant or a plant treating groundwater under the influence of surface water. In a conventional filtration treatment plant, softening plant, and iron and manganese removal plant, provisions should be made for applying disinfectant to the influent of each sedimentation basin, filter influent, and water entering the clearwell. Chlorine dioxide shall not be used as distribution system disinfection. Systems using chloramines as the disinfectant residual entering the distribution system must add and mix the chlorine prior to the addition of ammonia.

4.4.1. Contact time and point of application.

a. Due consideration shall be given to the contact time of the disinfectant in water with relation to pH, ammonia, taste-producing substances, temperature, bacterial quality, disinfection by-products formation potential and other pertinent factors. Disinfectant shall be

applied at a point that will provide adequate contact time. All required disinfectant contact time should be provided after filtration. All basins used for disinfection must be designed to minimize short-circuiting.

b. For surface water systems and ground water systems under the direct influence of surface water:
   1. The disinfectant contact time must be determined by Tracer Studies as explained in Appendix B of the "Guidance Manual for Surface Water System Treatment Requirements." The tracer study is required for a new treatment plant prior to receiving final approval from the department for permission to operate;
   2. The disinfection treatment must provide a sufficient CT (Disinfectant residual concentration multiplied by the contact time) value to ensure that the total treatment process achieves the required inactivation and/or removal of *Giardia lamblia* cysts and viruses. The percentage of *Giardia lamblia* cyst and virus removal by the disinfection process shall be determined by calculating the CT value and comparing the calculated CT value with the corresponding water characteristics on the CT tables in Appendix C of the Guidance Manual for Surface Water System Treatment Requirements; and
   3. Free residual chlorination is the preferred practice. If the system uses a disinfectant other than chlorine, the system must demonstrate to the department that the treatment process can satisfactorily inactivate and/or provide the required log removal of *Giardia lamblia* cysts and viruses.

c. For groundwater systems, the disinfection treatment must provide a sufficient CT value to ensure that the total treatment process achieves the required inactivation and /or removal of viruses. Free residual chlorination is the preferred practice.

4.4.2. Residual disinfectant.

a. Only free available chlorine or chloramine shall be used as the disinfectant to water entering the distribution system. Chlorine or chloramine shall be applied prior to the filters with a residual maintained through the filters, to the water entering the distribution system, and at distant points in the water distribution system. Chloramine, when used as the disinfectant, must provide breakpoint chlorination in the treatment process before converting the chlorine to chloramine.

b. The minimum disinfectant residual of water entering the distribution system shall be 1.0 milligrams per liter of free available chlorine or 2.0 milligrams per liter chloramine.

c. Minimum free residual at distant points in a water distribution system shall be 0.5 milligrams per liter. Chloramine residual, if

utilized, shall be 1.0 milligrams per liter at distant points in the distribution system.

4.4.3 Testing equipment.

Chlorine residual test equipment shall meet the requirements established in 10 CSR 60-5.010 and shall be capable of measuring residuals to the nearest 0.2 milligram per liter**.** All treatment plants serving a population greater than 3,300 shall be equipped with recording chlorine analyzers monitoring water entering the distribution system.

4.4.4 Other Disinfecting Agents.

Although disinfecting agents other than chlorine are available, each has usually demonstrated shortcomings when applied to a public water supply. Proposals for use of disinfecting agents other than chlorine, including ozone disinfectant, must be approved by the department prior to preparation of final plans and specifications.

4.4.5. Ozone Disinfectant.

4.4.5.1. Bench scale studies.

Prior to the use of ozone for primary disinfectant, bench scale studies must be conducted for ground water sources and full scale pilot studies must be conducted for surface water and ground water under the influence of surface water sources.

4.4.5.2. Chief operators.

Chief operators for water systems treating water with ozone must have the appropriate operator certification level required by the operator certification rules in 10 CSR 60-14.

4.4.5.3. Disinfectant residual.

Systems utilizing ozone for the primary disinfectant must provide for maintaining a residual of chlorine or chloramine in the distribution system.

4.4.6. Disinfection Byproduct and Precurser Removal and Control

Disinfection byproducts are formed when disinfectants react~~s~~ with naturally occurring organic substances. These organic substances, called "precursors," are a complex and variable mixture of compounds. Formation of disinfection byproducts is dependent on such factors as amount and type of disinfectant used, temperature, concentration and type of precursor, pH, and contact time.

Pilot or full-scale studies for disinfection byproduct and precursor removal and control shall be performed. Any full plant trial studies or modifications to an existing treatment process shall be pre-approved by the department. Water treatment plants for which construction is begun after the effective date of this document shall be designed with clearwells and other plant finished water storage sized to provide all of the required disinfectant contact time, CT, after filtration. These storage facilities must be baffled or otherwise designed to assure optimum detention and calculations submitted to support the basis of the design.

4.4.6.1. Methods of controlling precursors at the source.

a. Selective withdrawal from reservoirs. Varying depths may contain lower concentrations of precursors at different times of the year. Analyses for chlorophyll A and B may be useful in selecting withdrawal locations and in controlling plankton.

b. Plankton Control. Algae and their by-products act as disinfection byproduct precursors.

1. Only algaecides approved by the department for use in potable water may be used for algae control in drinking water sources. Equipment for routine sampling and microscopic examination of the source water shall be available to assure that over-treatment does not occur. The minimum equipment must include a microscope with built-in illumination, a Sedgwick-Rafter counting cell, and algae identification manuals.
2. Destratification of a water supply reservoir to reduce nutrients and thus plankton growth shall be supported by studies done on similar lakes that have been destratified. Furthermore, consideration shall be given to handling increased plankton growth during the first years of the operation. Watershed conditions that result in continuous high nutrient flow to a reservoir may negate any benefits in disinfection byproduct formation provided by destratification.
3. Alternative sources of better quality water should be considered, where available.

4.4.6.2. Removal of disinfection byproduct precursors and control of disinfection byproduct formation.

Pilot or full-scale studies for disinfection byproduct and precursor removal and control shall be performed. In addition, source water tests that cover at least a full calendar year are necessary to assure that the treatment facilities will handle all source water conditions.

a. Moving the point of chlorination to minimize disinfection byproduct formation.

b. Removal of precursors prior to chlorination by practicing enhanced coagulation or softening and by optimizing treatment processes:

1. Enhanced Coagulation and Softening.
    1. Systems treating surface water or ground water under the direct influence of surface water shall provide conventional water treatment. For surface water, conventional treatment is two stages of treatment provided as: primary rapid mix, flocculation and sedimentation followed by secondary rapid mix, flocculation and sedimentation, operated in series and followed by filtration and disinfection contact storage. For ground water under the direct influence of surface water, conventional treatment is defined as one stage of treatment consisting of secondary rapid mix, flocculation and sedimentation and followed by filtration and disinfection contact storage.
    2. For existing treatment plants exceeding disinfection by-product MCLs or not meeting TOC removal requirements, a complete engineering study of all of the treatment processes shall be done to assure they are operating at their optimum. This study shall include a review of influent and effluent facilities for each treatment basin, evidence of basin short-circuiting, basin sizes and geometry, mixer design and chemicals fed and their efficiency. Modifying existing processes to assure optimum performance shall be considered.
    3. For proposed treatment plants, provide flexibility in chemical application and mixing to optimize treatment. Continuous monitoring and recording equipment shall be provided where appropriate.
2. Adding oxidizing agents such as potassium permanganate, ozone, or chlorine dioxide to reduce the chlorine demand and thus the disinfection byproduct formation. Possible health effects of the byproducts produced by the oxidizing agents must be taken into consideration.
3. Adsorption by powdered activated carbon (PAC). Studies using a variety of powdered carbons should be done to find the dosages required, the best application points and the most effective and least costly carbons. Provisions should be made for adding and mixing the carbon solution before any other treatment chemicals are added and for providing a minimum 20 minute contact time with the water.
4. Lowering the pH to inhibit the reaction rate of chlorine with precursor materials and to improve coagulation and

removal of the precursors. Pilot or full plant trials should be done to determine the chemical processes required to stabilize the water. Noncorrosive finished water is required to meet secondary maximum contaminant levels and to assure compliance with the lead and copper rules in 10 CSR 60-15. Written approval of the department shall be obtained before conducting any full plant trials or changing the treatment process.

5. Using various combinations of treatment to remove disinfection byproduct precursors. Combinations of treatment may be necessary to successfully meet disinfection byproduct standards.

4.4.6.3 Removal of disinfection byproducts.

a. Aeration - by air stripping towers.
b. Adsorption by:
    1. Granular activated carbon (GAC).
        1. Methods shall be provided for monitoring carbon bed performance to determine when the carbon is exhausted for disinfection byproduct removal.
        2. Methods shall be provided for monitoring the carbon beds to assure that microbiological growth in the carbon will not pass into the drinking water. Carbon contacter design shall allow for backwashing or cleaning of the carbon bed to control microbiological growth. Facilities for feeding a disinfectant and for providing disinfection contact time shall be provided following granular activated carbon adsorption facilities.
        3. Carbon shall be chosen to minimize carbon grain breakdown or methods provided to prevent carbon fines from passing into the drinking water.
        4. Consideration shall be given to ease of carbon removal and replacement.
    2. Synthetic Resins.
        1. Any resin proposed shall have NSF certification for use with potable water concerning leaching of chemicals into water.
        2. Methods shall be provided for monitoring resin bed performance to determine when the resin is exhausted for disinfection byproduct removal.
        3. Methods shall be provided for monitoring and controlling microbiological growth in the resin.
        4. Resin shall be chosen to minimize breakdown or methods provided to prevent resin fines from passing into the drinking water.

5. Consideration shall be given to ease of resin removal and replacement.

4.4.6.2 Use of alternative disinfectants.

Disinfectants that react less with disinfection byproduct precursors may be used as long as pathogen control is maintained and disinfection byproduct and precursor removal standards are met. When using alternative disinfectants, facilities must maintain a distribution system residual of free chlorine or chloramines. Possible health effects of the byproducts produced by alternative disinfectants must be taken into consideration. Written approval of the department shall be obtained before changing disinfectants. The alternative disinfectants listed below may be used.

a. Chlorine Dioxide. Chlorine dioxide shall not be used as a distribution system disinfectant.

b. Chloramines. Chloramines are generally not suitable as primary disinfectants but may be used to provide required distribution system residuals. The following shall be considered before using chloramines.

   1. Existing facilities wanting to install chloramine disinfection shall do a disinfectant profile through the treatment plant and develop an inactivation benchmark. The results of the profile shall be submitted to the department along with the written request to change disinfectants.
   2. Nitrites and nitrates are primary health contaminants and must be kept below the maximum contaminant levels. Therefore, sampling in the distribution system shall be done to find if nitrification is occurring.
   3. Heterotrophic bacteria studies should be done routinely to assure that biological growths are controlled throughout the distribution system. Any study should include sufficient sampling to identify all problem areas.
   4. To help control microbial growths, break point chlorination should be obtained before adding ammonia to the water and converting to chloramines.
   5. Chlorination facilities must be provided that will allow free chlorine residuals to be maintained throughout the distribution system.
   6. All systems must notify all of its customers before converting to chloramines. Special care must be taken notify dialysis clinics, doctors clinics, hospitals, nursing homes, and home dialysis patients.

c. Ozone. Analyses for bromate production should be done early in the design process. Biological mediation or other byproduct

removal processes shall be included as a part of the ozone facility design.

4.5. Softening.

The softening process selected must be based upon the mineral quality of the raw water and the desired finished water quality in conjunction with requirements for disposal of residuals or brine waste, cost of plant, cost of chemicals and plant location. Applicability of the process chosen shall, be demonstrated.

4.5.1 Lime or lime-soda process.

Design standards for rapid mix, flocculation, and sedimentation are in subsection 4.2. Additional consideration must be given to the following process elements:

a. Hydraulics. When split treatment is used, the bypass line should be sized to carry total plant flow, and an accurate means of measuring and splitting the flow must be provided;
b. Aeration. Determinations should be made for the carbon dioxide content of the raw water. When concentrations exceed 10 milligrams per liter, the economics of removal by aeration as opposed to removal with lime should be considered if it has been determined that dissolved oxygen in the finished water will not cause corrosion problems in the distribution system. When split treatment is utilized, the split should be prior to aeration, and the re-blending prior to filtration;
c. Chemical feed point. Lime should be fed directly into the rapid mix basin;
d. Rapid mix. Rapid mix basins must provide 30 seconds detention time with adequate velocity gradients to keep the lime particles dispersed;
e. Stabilization. Equipment for stabilization of water softened by the lime or lime-soda process is required;
f. Residuals collection and disposal.
    1. Mechanical residuals removal equipment shall be provided in the sedimentation basin; and
    2. Provisions must be included for proper disposal of softening residuals in accordance with regulations in 10 CSR 20;
g. Disinfection. The use of excess lime is no substitute for disinfection; and
h. Plant start-up. The plant processes must be manually started following shutdown, unless approved by the department where automatic monitoring controls are provided.

4.5.2. Cation exchange process.

a. Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration are of concern.

b. Pre-treatment requirements. Iron, manganese, or a combination of the two, should not exceed 0.3 milligram per liter in the water as applied to the ion exchange resin. Pre-treatment is required when the content of iron, manganese, or a combination of the two, is one milligram per liter or more (see Section 4.6). Waters having five units or more turbidity should not be applied directly to the cation exchange softener.
c. Design. The units may be of pressure or gravity type, of either an upflow or downflow design. Automatic regeneration based on volume of water softened should be used unless manual regeneration is justified and is approved by the department. A manual override shall be provided on all automatic controls.
d. Exchange capacity. The design capacity for hardness removal should not exceed 20,000 grains per cubic foot when resin is regenerated with 0.3 pound of salt per kilograin of hardness removed.
e. Depth of resin. The depth of the exchange resin should not be less than three feet.
f. Flow rates. The rate of softening should not exceed seven gallons per minute per square foot of bed area and the backwash rate should be six to eight gallons per minute per square foot of bed area. Rate-of-flow controllers or the equivalent must be installed for the above purposes.
g. Freeboard**.** The freeboard will depend upon the specific gravity of the resin and the direction of water flow. Generally, the washwater collector should be 24-inches above the top of the resin on downflow units.
h. Underdrains and supporting gravel. The bottoms, strainer systems and support for the exchange resin shall conform to criteria provided for rapid rate gravity filters.
i. Brine distribution. Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.
j. Cross connection control. Backwash, rinse, and air relief discharge pipes must be installed in such a manner as to prevent any possibility of back-flow.
k. Bypass. A bypass must be provided around softening units to produce a blended water of desirable hardness. Totalizing meters must be installed on the bypass line and on each softening unit. The bypass line must have a shut-off valve and should have an automatic proportioning or regulating device. In some installations, it may be necessary to treat the bypassed water to obtain acceptable levels of iron and/or manganese in the finished water.
l. Additional limitations. Silica gel resins should not be used for waters having a pH above 8.4 or containing less than 6 milligrams per liter silica and should not be used when iron is present. When the applied water contains a chlorine residual, the cation exchange resin shall be of a type that is not damaged by residual chlorine. Phenolic resin should not be used.

m. Sampling taps. Sampling taps must be provided for the collection of representative samples. The taps shall be located to provide for sampling of the softener influent, effluent and blended water. The sampling taps for the blended water shall be at least 20 feet downstream from the point of blending. Sampling taps should be provided on the brine tank discharge piping.

n. Brine and salt storage tanks.

   1. Salt dissolving or brine tanks and wet salt storage tanks must be covered and must be corrosion-resistant.
   2. The make-up water inlet must be protected from backflow. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank. The tanks should be provided with an automatic declining level control system on the make-up water line.
   3. Wet salt storage basins must be equipped with manholes or hatchways for access and for direct dumping of salt from truck or railcar. Openings must be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs.
   4. Overflow, where provided, must be protected with a corrosion resistant screen and must terminate with either a turned-down bend having a proper free fall discharge or a self-closing flap valve.
   5. Two wet salt storage tanks or compartments designed to operate independently should be provided.
   6. The salt shall be supported on graduated layers of gravel placed over a brine collection system.
   7. Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered.

o. Salt and brine storage capacity. Total salt storage should have sufficient capacity to store in excess of 1½ carloads or truckloads of salt, and provide for at least 30 days of operation.

p. Brine pump or eductor. An eductor may be used to transfer brine from the brine tank to the softeners. If a pump is used, a brine measuring tank or means of metering should be provided to obtain proper dilution.

q. Stabilization. Stabilization for corrosion control shall be provided. An alkali feeder shall be provided except when exempted by the department.

r. Waste disposal. Disposal of brine waste must be in accordance with Clean Water Commission Regulations.

s. Construction materials. Pipes and contact materials must be resistant to the aggressiveness of salt. Plastic and red brass are acceptable piping materials. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine.

t. Housing. Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.

4.6. Aeration.

Aeration may be used to help remove offensive tastes and odors due to dissolved gases from decomposing organic matter, or to reduce or remove objectionable amounts of carbon dioxide, hydrogen sulfide, etc., and to introduce oxygen to assist in iron and/or manganese removal. The design criteria in this section 4.6. is not intended for facilities to remove organics.

4.6.1 Forced or induced draft aeration.

Forced or induced draft aeration devices shall:

a. Include a blower with a weatherproof motor in a tight housing and screened enclosure;
b. Insure adequate counter current of air through the enclosed aerator column;
c. Exhaust air directly to the outside atmosphere;
d. Include a down-turned and 18-mesh screened air outlet and inlet;
e. Be designed such that air introduced in the column shall be as free from obnoxious fumes, dust, and dirt as possible;
f. Be designed such that one side or a portion of one side may be opened for inspection and maintenance of the interior of the aerator, and located so that all aspects of the aerator are easily accessible for maintenance;
g. Provide loading at a rate of one to five gallons per minute for each square foot of total tray area;
h. Insure that the water outlet is adequately sealed to prevent unwarranted loss of air;
i. Discharge through a series of five or more trays with separation of trays not less than six inches;
j. Provide distribution of water uniformly over the top tray;
k. Be resistant to the aggressiveness of the water and dissolved gases;
l. Provide for bypassing the treatment process with aerated water to facilitate disposal of iron residue during cleaning;
m. Not be located inside a building; and
n. Be constructed of stainless steel or aluminum.

4.6.2 Pressure aeration.

Pressure aeration may be used for oxidation purposes only if pilot plant study indicates the method is applicable. It is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to:

a. Give thorough mixing of compressed air with water being treated;
b. Provide screened and filtered air, free of obnoxious fumes, dust, dirt, and other contaminants;
c. Have the necessary delivery capacity of air at 5 psi to 10 psi pressure, depending upon depth of water in the basin;
d. Give a detention period of 5 to 15 minutes based on design flow; and
e. Provide from 0.005 cubic foot to 0.2 cubic foot per gallon of water aerated.

4.6.3. Spraying.

a. Distribute water through spray nozzles with a pressure of approximately ten psi at the throat;
b. The area covered by the spray from each nozzle from about 10 to 200 square feet;
c. The output per nozzle from 40 to 175 gallons per minute, depending upon the type of nozzle; and
d. Protection from loss of spray water by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45 degrees.

4.6.3 Other methods of aeration.

Other methods of aeration may be used if applicable to the treatment needs, subject to the approval of the department.

4.6.4 Protection of aerators.

All aerators except those discharging to lime softening or clarification plants shall be protected from contamination from birds, insects, and windborne debris.

4.6.5 Disinfection.

Groundwater supplies exposed to the atmosphere by aeration must receive chlorination as the minimum additional treatment.

4.6.6 Bypass.

A bypass shall be provided for all aeration units.

4.6.7 Corrosion control.

The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary.

4.7. Iron and Manganese Control

Iron and manganese control, as used in this section, refers solely to treatment processes designed specifically for this purpose. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment process must meet specific local conditions as determined by engineering investigations, including chemical analysis of representative samples of water to be treated, and receive the approval of the department. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Allowances must be made for deterioration of groundwater quality, over time, and for variations in ground water quality at different locations. Testing equipment and sampling taps shall be provided as specified in sections 2.8 and 2.10**.**

4.7.1. Removal by oxidation, detention and filtration.

a. Oxidation. Oxidation may be by aeration, as indicated in Section 4.6 or by chemical oxidation with chlorine, potassium permanganate, ozone, or chlorine dioxide.

b. Detention.

1. Reaction-A minimum detention time of two hours shall be provided following aeration for water containing iron or manganese to insure that the oxidation reactions are as complete as possible. This minimum detention time may be decreased only where indicated by a pilot plant study. The detention basin should be designed with sufficient baffling to prevent short-circuiting.
   - i. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process.
   - ii. Provisions shall be made for providing rapid mix of 30 seconds.
2. Sedimentation-A sedimentation basin in place of a detention basin shall be provided when treating water containing 4 mg/L or more iron and/or manganese, or where chemical coagulation is used to reduce the load on the filters. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process. Coagulant addition and rapid mixing should also be provided. Facilities for rapid mixing flocculation and sedimentation should be designed in accordance with section 4.1. Provisions for residuals removal shall be made. The detention basin shall be designed with sufficient baffling to prevent short-circuiting. The detention time in the sedimentation basin shall be based on the total concentration of iron and/or manganese in the water to be treated.
   - i. The following are the minimum detention times at different concentration ranges of iron and /or manganese exceeding 4 mg/L:
     1. 4mg/L to 9 mg/L - four hours detention time;
     2. 10mg/L to 20mg/L **-** six hours detention time; and

3. Above 20 mg/L – to be determined from pilot or full-scale demonstration plant study.

ii. The following provisions shall be included for combined reaction and sedimentation basins:

1. Provisions shall be made for adding chemicals for pH adjustment and enhancement of the oxidation process.
2. Provisions shall be made for adding a coagulant; and
3. Provisions shall be made for providing rapid mix of 30 seconds.

c. Removal by the lime-soda softening process. See paragraph 4.5.1.

d. Removal by manganese greensand or other propriety filter media.

i. This process consists of a continuous feed of potassium permanganate or other oxidizing chemical to the influent of a filter. Pilot studies must be done to obtain department approval.

ii. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.

iii. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the cost of the chemical.

iv. Anthracite media cap of at least six inches shall be provided over manganese greensand.

v. Normal filtration rate is three gallons per minute per square foot.

vi. Normal wash rate is eight to ten gallons per minute per square foot, or as recommended by the media manufacturer.

vii. Air washing should be provided.

viii. Sample taps shall be provided:

1. Prior to application of permanganate;
2. Immediately ahead of filtration; and
3. At the filter effluent.

ix. Sample taps should be provided:

1. At a point between the media layers; and
2. Halfway down the media when only one type media is utilized.

e. Removal by ion exchange. This process of iron and manganese removal should not be used for water containing more than 0.3 milligram per liter of iron, manganese or combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen.

f. Sequestration by polyphosphates.

1. This process shall not be used when iron, manganese, or combination thereof exceeds 1.0 milligram per liter. The total phosphate applied shall not exceed 10 milligrams per liter as orthophosphate.

Where phosphate treatment is used, provisions for disinfecting the water must be provided.

2. Feeding equipment shall conform to the requirements of Chapter 5 of this document.
3. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 milligrams per liter free chlorine residual.
4. Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation, or disinfection if no iron or manganese removal treatment is provided.
5. Phosphate chemicals must be acceptable to the department.

g. Sequestration by sodium silicates.

1. Sodium silicate sequestration of iron and manganese is appropriate only to groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum dose needed. Chlorination must precede the introduction of sodium silicate. Addition of sodium silicate must be within 15 seconds after the addition of chlorine.
2. Sodium Silicate addition is applicable to waters containing up to 2 mg/L of iron, manganese or combination thereof.
3. Equipment must be provided so that chlorine residuals can be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.
4. The amount of silicate added shall be limited to 20 mg/L as $Si0_2$, but the amount of added and naturally occurring silicate shall not exceed 60 mg/L as $Si0_2$.
5. Feeding equipment shall conform to the requirements of Chapter 5 of this document.
6. Sodium silicate shall not be applied ahead of iron or manganese removal treatment.
7. Quality of sodium silicate must be acceptable to the department.

4.8. Control of Organic Contamination.

Controlling organic contamination is an area of design that requires pilot studies and early consultation with the department. Where treatment is proposed, the best available technology shall be provided to reduce organic contaminants to the lowest practical levels.

4.8.1 Engineering Report.

Except for temporary, emergency treatment conditions, particular attention shall be given to developing an engineering report that, in addition to the normal determinations in section 1.1, includes the following:

a. Types of organic chemicals, sources, concentrations, frequency of occurrence if in surface water or estimated residence time within the aquifer and flow characteristics if in ground water, water pollution abatement schedule, etc.;
b. Possible treatment alternatives;
c. Results of bench, pilot, or full scale testing, demonstrating the effectiveness and cost of the treatment alternatives; and
d. A determination of quality and/or operational parameters which may serve as the best measurement of treatment performance, and a corresponding monitoring and process control program.

4.8.2 Control Alternatives.

In general, the design of control and treatment alternatives for organic contamination requires pilot or full scale testing. Collection of data pertinent to design is often complicated and lengthy. A permanent engineering solution for organic contamination may take significant time to develop. The following alternatives should be considered:

a. Alternative source development or purchase of water from nearby unaffected water systems may be a more expedient solution;
b. Modifications of existing treatment to enhance organic removal;
c. Air stripping for volatile organics. In designing the air stripping tower, consideration should be given to:
    1. Materials for tower, packing, and piping that are acceptable for use in contact with potable water;
    2. Providing a moisture barrier (de-mister);
    3. Metering the water flow to the tower;
    4. Metering the air flow to the tower;
    5. Providing influent and effluent sampling taps;
    6. Disinfecting the water passing through the tower;
    7. Designing the tower and air to water ratio to reduce the critical contaminants to the lowest practical level;
    8. The air discharge meeting the air quality standards of the Missouri Air Conservation Commission;
    9. Provision for easy inspection, maintenance, and cleaning of the packing materials. Iron and manganese precipitation, carbonate deposition, and biological fouling are potential problems;
    10. Chemical stability of the finished water; and
    11. Acceptable supply during periods of maintenance and operation interruptions; and
d. Adsorption by granular activated carbon. Consideration should be given to:
    1. Determining the filter isotherm for the particular contaminant to be removed, and the minimum contact time with the carbon bed that is necessary for removing the contaminant;
    2. Using contact units rather than replacing portions of existing filter media;

3. Series and parallel flow piping configurations to minimize the effect of breakthrough without reliance on continuous monitoring;
4. Providing at least two units. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved rate. Where more than two units are provided, the contactors shall be capable of meeting the design capacity at the approved rate with one (largest) unit out of service;
5. Using virgin carbon. Although reactivated carbon may present an economic advantage at large water treatment plants, such an alternative may be pursued only with the preliminary endorsement of the department. If regenerated carbon is accepted, only carbon previously used for potable water treatment can be used for this purpose. Transportation and regeneration facilities must not have been used for carbon put to any other use; and
6. Acceptable means of spent carbon disposal, pursuant to hazardous waste management regulations in 10 CSR 25.

4.9. Stabilization.

Water that is unstable due either to natural causes or to subsequent treatment should be stabilized. Chemicals can be fed to provide a stable to slightly depositing water or to mitigate the solubility of targeted parameters.

4.9.1. Carbon dioxide addition.

Carbon dioxide is generally fed at plants that lime soften to stop the softening process and prevent excess deposition of calcium carbonate onto filters and in the water distribution system. Carbon dioxide storage and feeding facilities shall meet the requirements of Chapter 5 of this document.

4.9.2. Acid addition.

a. Feed equipment shall conform to Chapter 5 of this document.
b. Adequate precautions shall be taken for operator safety, such as the provision of personal protective equipment, transfer pumps and not adding water to concentrated acid.
c. If bulk storage is used, containment walls that will adequately hold the acid must be provided.

4.9.3. Phosphates.

a. The feeding of phosphates may be applicable for sequestering calcium in lime-softened water, corrosion control, and in conjunction with alkali

feed following ion exchange softening. However, feeding phosphates is not acceptable as a substitute for proper operation and maintenance of the existing coagulation, filtration or recarbonation processes.

b. Feed equipment shall conform to Chapter 5 of this document.

c. Phosphate quality must be acceptable to the department.

d. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 milligrams per liter free chlorine residual.

e. Phosphates can act as a nutrient for biological growth in water distribution systems. Therefore, disinfection equipment shall be provided that is sufficient to maintain disinfectant residuals throughout the distribution system at levels necessary to control biological growths. Heterotrophic bacteria studies should be done routinely to assure that biological growths are controlled through out the distribution system.

4.9.4. Split Treatment.

Treatment plants designed to use "split treatment" should also contain facilities for further stabilization by other methods. A series of tests for iron and manganese shall be performed on all of the water sources before considering split treatment. Iron and manganese tests shall be done upon startup and throughout the pumping cycle of each source to find out if surges of high concentrations occur. Plants that soften surface water shall not blend water for stabilization. Because of deposition, all blending for stabilization shall be done before filtration and bench tests shall be done to determine if blending alone will sufficiently stabilize the water.

4.9.5. Alkali Feed.

Aggressive water created by ion exchange softening shall be neutralized by an alkali feed that does not contain sodium. Alkali feeding facilities shall be provided for all ion exchange water softening plants except when exempted by the department. Adequate rapid mixing of the alkali with the water flow shall be provided. Turbidity monitoring may be necessary to assure that the alkali feed does not make the water cloudy.

4.9.6. Carbon dioxide reduction by aeration.

The carbon dioxide content of aggressive water may be reduced by aeration. Tests shall be done and data submitted to assure that the type of aerator proposed will provide the carbon dioxide reductions desired.

4.9.7. Other treatment.

Other treatment for controlling corrosive water by the use of sodium silicate and sodium bicarbonate may be used with the written approval of the department. Any proprietary compound must receive the specific written

approval of the department before use.

4.9.8. Water unstable due to biochemical action in distribution system.

Unstable water resulting from bacterial decomposition of organic matter biochemical action within tubercles, and reduction of sulfates to sulfides should be prevented by maintaining a free chlorine residual of 0.5 mg/L throughout the distribution system. This may be done by boosting chlorine residuals or by a program of routine water main flushing.

4.9.9. Control.

Laboratory equipment shall be provided for determining the effectiveness of stabilization treatment. The preferred method of determining stability is the calcium carbonate stability test using a continuous calcium carbonate contactor and pH, alkalinity, and calcium hardness analysis equipment.

4.10. Taste and Odor Control.

Provision shall be made for the control of taste and odor at all surface water treatment plants. Equipment for routine sampling and microscopic examination of the source water shall be available to the public water supply. Taste and odor removal chemicals shall be added sufficiently ahead of other treatment processes to ensure adequate contact time for an effective and economical use of the chemicals. Where severe taste and odor problems are encountered, in-plant or pilot plant studies, or both, are required.

4.10.1 Flexibility.

Plants treating water known to have taste and odor problems should have equipment that makes several control processes available so the operator will have flexibility in operation. At a minimum, equipment for feeding powdered activated carbon and potassium permanganate should be provided. In addition, plant design should provide for feeding these chemicals at multiple locations in the treatment process.

4.10.2. Chlorination.

Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved. Excessive potential disinfection byproduct production through this process should be avoided by adequate bench-scale testing prior to design.

4.10.3. Chlorine dioxide.

Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste and odor that is treatable by an oxidizing compound.

Provisions shall be made for proper generating, feeding, storing and handling of all chemicals associated with chlorine dioxide.

4.10.4. Powdered activated carbon.

Powdered activated carbon should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several points is required. Activated carbon should not be applied near the point of chlorine application. Flash mixing shall be provided to assure an even dispersion of the carbon in the water. The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odors involved**.** Provision should be made for adding from 0.1 milligram per liter up to at least 50 milligrams per liter at the maximum design flow of the treatment facilities.

4.10.5. Granular activated carbon adsorption units.

See subparagraph 4.8.2.d.

4.10.6. Copper sulfate and other copper compounds.

Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be controlled to prevent copper concentrations more than 1.0 milligrams per liter as copper in the plant effluent or distribution system. Only compounds approved by the department for use with potable water may be used**.** Care shall be taken to assure an even distribution. Equipment for routine sampling and microscopic examination of the source water shall be provided at the water plant to assure that over treatment does not occur. Approved equipment to daily test for copper concentrations shall be provided.

4.10.7. Aeration.

Literature searches or pilot studies shall be done to assure that the particular taste and odor-causing compounds can be removed by aeration before submitting plans and specifications.

4.10.8. Potassium permanganate.

Application of potassium permanganate is recommended, providing the treatment shall be designed so that finished water manganese concentrations do not exceed the 0.05 mg/L secondary maximum contaminant level. Equipment to daily test for manganese concentrations shall be provided**.**

4.10.9. Ozone.

Ozonation can be used as a means of taste and odor control. Adequate

contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors. Analyses for bromate should be done early in the design process. Biological mediation or other byproduct removal processes shall be included as a part of the ozone facility design.

4.10.10. Other methods.

The decision to use any other methods of taste and odor control shall be made only after careful laboratory and/or pilot plant tests and after obtaining the approval of the department.

4.11. Waste Handling and Disposal

Provisions shall be made for proper disposal of water treatment plant sanitary and process wastes such as discharges from water closets, urinals and lavatories and laboratory wastes, filter backwash water, brines and clarification, softening, iron and manganese residuals. All waste discharges are governed by regulatory agency requirements and shall be handled or treated to meet the applicable requirements. Additional permits and approvals other than those issued by the Missouri Public Drinking Water Program may be required. It is the responsibility of the water system officials or their representatives to submit all required applications, submittals, and permit fees to the appropriate agencies and to obtain all necessary permits.

All wastewater discharges shall meet the general water quality criteria in 10 CSR 20-7.031(3) and any additional criteria on the specific type of wastewater discharged. Treatment plant process residuals can be handled as a solid waste or through the wastewater permit process. If handled as a solid waste, residuals shall be hauled to a permitted sanitary landfill for disposal. Permanent residual storage makes the storage facilities a solid waste disposal site requiring the appropriate studies and permits. If handled through the wastewater permit process, residuals are land applied for agronomic purposes.

If the process residuals are to be land applied, those chemical characteristics that will affect its land application must be discussed as a part of the engineering report submitted to the department. Estimates of the amount of land required for disposal and of the years that the land can be used must be included. Process waste handling facilities shall be designed to be compatible with the drinking water treatment facilities and not adversely affect drinking water treatment. The process waste handling facilities must be designed to be compatible with the resources and capabilities of the specific system and its operators. Methods and equipment for efficiently removing and disposing of process waste must be part of the handling facility design. If land application is to be done by a contractor information must be submitted on the arrangements with a contractor to remove and land apply the residuals. The method and information used in estimating the amount and type of process waste produced must be part of the engineering report submitted to the

department. In locating waste disposal facilities due consideration shall be given to preventing potential contamination of water sources, treatment facilities, and raw and finished water piping.

4.11.1. Earthen Lagoons and Holding Basins.

All earthen lagoons and holding basins shall be designed and constructed to meet the requirements of 10 CSR 20-8.020(3) for design of small sewerage works for waste stabilization ponds and shall be provided with the following:

a. a location free from flooding or protected to a minimum one in ten year flood;
b. a means of diverting surface water so that it does not flow into the lagoons;
c. a minimum usable depth of five feet;
d. a minimum freeboard of two feet;
e. an adjustable decanting device;
f. an effluent sampling point; and
g. a method to prevent brush and weed growth on the interior slopes of the lagoon berms. If rip rap is used, it should have a minimum depth of 18-inches and extend from the toe of each berm to the top of the slope. The rip rap should be provided in at least two layers with the first 12-inches consisting of mixed rock 2-inches and smaller in diameter.

4.11.2. Sanitary waste.

a. Shall be discharged directly to a permitted sanitary sewer system, when feasible, or to an adequate on-site treatment facility approved by the department;
b. Shall not be discharged to a process waste lagoon or backwash water lagoon or to a residual holding basin or tank;
c. May be discharged to sewage holding tanks when site restrictions, geology, or soil type prevents using a wastewater lagoon or septic tank and tile field. Sewerage holding tanks must be routinely pumped out and the waste hauled to a permitted wastewater treatment facility for disposal. The name of the wastewater treatment facility where the waste will be hauled for disposal must be part of the submittal to the department. Holding tank location must provide for easy access by hauling equipment. Holding tanks must be equipped with the necessary devices to effectively access and remove the waste from the holding tank.
d. Laboratory sample taps that run continuously while the plant is in operation can be discharged to a backwash holding basin or residuals lagoon by means of drainage that is separate from the laboratory sink and plant sanitary sewerage piping system.

4.11.3. Brine waste.

Brine waste from ion exchange plants, demineralization plants, or other plants that produce brine waste may be discharged to:

a. Sanitary sewers with the approval of the local wastewater system authority; or
b. A flowing stream provided the stream flow is adequate to provide the necessary dilution.

4.11.4. Lime softening residuals

Lime softening residuals may be land applied at agronomic rates. Residuals from plants using lime to soften water varies in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. These characteristics govern the amount of residual that can be applied to any specific piece of ground. The engineering report submitted to the department shall include a discussion of the expected residual characteristics. Methods of treatment and disposal are as follows:

a. Lagoons may be used to temporarily store residuals until they can be removed for final disposal. Storage lagoon(s):
    1. Must be designed to be cleaned periodically;
    2. Submittals shall include descriptions and specifications on residuals removal, handling, processing and disposal equipment or shall include information on the arrangements with a contractor to remove and land apply the residuals.
    3. Submittals shall include a copy of facility specific, standard, operating procedures for residual removal and disposal. The operating procedures shall include a discussion of the manpower necessary for proper operation of the facilities;
    4. Shall be designed to provide a total of at least six months of residual storage calculated on the basis of 0.7 acre per million gallons per day per 100 milligrams per liter of hardness removed based on a usable lagoon depth of at least five feet;
    5. Must have at least two but preferably more, storage cells in order to give flexibility in operation; and
    6. Shall be designed to produce a wastewater effluent that meets the Missouri Clean Water Commission effluent and water quality standards and that is satisfactory to the department.
b. Discharge of lime residuals to sanitary sewers should be avoided since it may cause both liquid and residual volume problems at the sewage treatment plant and sewer plugging problems. This method shall be used only when the sewerage system has adequate capacity and ability to handle the lime residuals.
c. Disposal at a permitted sanitary land fill can be done as either a solid or liquid if the landfill can and will accept such waste, in accordance with solid waste management regulations.
d. Mixing of lime residuals with waste activated sludge may be considered as a means of co-disposal. All necessary approvals from the local wastewater system operating authority shall be obtained. Pilot studies or trial runs to determine the impact of the lime residuals on the

wastewater treatment facilities are recommended.

e. Mechanical drying of residuals may be considered. Pilot studies on a particular plant waste are required.
f. Calcination of residuals may be considered. Pilot studies on and detailed analyses of a particular plant waste are required.
g. Lime residual drying beds shall be constructed according to 10 CSR 20-8.170(8) for sludge drying beds

4.11.5. Clarification and Coagulation Residuals

An acceptable means of final residual disposal shall be provided as a part of the facility design and included in the engineering report. Clarification and coagulation residuals handling and disposal may consist of any of the following:

a. Mechanical concentration: A pilot plant study is required to design a mechanical residuals concentration installation. An engineering report explaining the findings and including data verifying the results of the pilot study shall be provided as a part of the Application for Construction Approval;
b. Freezing: Freezing changes the nature of clarification/coagulation residuals and allows it to be dried. Missouri weather does not allow natural freezing to be used as a reliable method and the department will not approve a proposal depending on natural freezing. A pilot study shall be done to design a residuals freezing installation. An engineering report explaining the findings and including data verifying the results of the pilot study shall be provided as a part of the Application for Construction Approval;
c. Acid treatment: Acid treatment of residuals for alum recovery has been done in some large water systems. Because acid dissolution is non-selective and will release natural organic matter, iron, heavy metals, and other contaminants present in the residuals, bench top or pilot studies must be done and the product produced analyzed to determine if undesirable chemicals will be produced. An engineering report explaining the findings and including results of all analyses must be submitted as a part of the Application for Construction Approval. These contaminants must be removed before the recovered alum can be used in drinking water treatment;
d. Discharge to sanitary sewer: Clarification/coagulant residuals may be discharged directly to a sanitary sewer if the wastewater treatment facilities are designed to remove and process the residuals. Because the residuals are not biodegradable and will settle and interfere with their operation, the department will not approve discharging residuals to systems using wastewater stabilization ponds or to wastewater plants using mechanical treatment unless they have facilities to remove the residuals before the biological treatment processes. The following shall be done to obtain an approval to discharge process residuals to a sanitary sewer system:

1. Obtain a letter of approval from the owner or operating authority of the sewerage system and submit a copy to the department;
2. Submit an engineering report explaining the impact of the residuals on the wastewater treatment facility and its sludge drying and handling facilities;
3. Submit evidence that the wastewater collection system, the wastewater treatment facilities and its sludge handling facilities are capable of handling the additional hydraulic and solids loading;
4. Because clarification / coagulant residuals may reduce the ability to dry bio-solids, pilot studies should be done to determine the ability of the wastewater facilities to handle the combined sludge; and
5. A holding basin for controlled discharge may be required; and

e. Lagoons: Lagoons may be used as a method of temporarily storing clarification/coagulant residuals.
   1. Lagoons shall be designed to produce an effluent that meets the Missouri Clean Water Commission effluent and water quality standards and that is satisfactory to the department.
   2. Lagoon size shall be calculated using the total amount of chemicals used plus a factor for turbidity. Unless justification is submitted for using another method clarification/coagulant sludge volume shall be calculated using the following formula:

      S lb/mg = 8.34 lb/gal X ((D mg/L ÷ 4) + Turbidity NTU + PAC mg/L)

      S lb/mg = Residual solids in pounds per million gallons of raw water pumped
      D mg/L = Coagulant dosages in milligrams per liter
      Turbidity NTU = average raw water turbidity
      PAC mg/L = powdered activated carbon dosage in milligrams per liter.

      To get the total volume of residuals, this product must be divided by the percent solids of the residuals. Total lagoon capacity shall provide at least six months of residual storage. When the residual lagoons are used for both residuals storage and filter backwash handling, the total capacity shall provide at least 12 months of storage.

   3. Lagoons must have at least two, but preferably more, storage cells in order to give flexibility in operation.

4.11.6. Iron and Manganese Residuals and Wastewater.

Iron and manganese waste are regulated under the Missouri Clean Water Commission regulations by effluent limits set on iron and manganese concentrations. Waste filter wash water and settling basin residuals from iron and manganese removal plants may be processed and disposed of as

follows:

a. Sand drying filters may be used to process waste filter wash water and settling basin residuals from treatment units that have automatic residual removal facilities. Sand filters shall have the following features:
    1. Total filter area, regardless of the volume of water to be handled, should be no less than 100 square feet. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required;
    2. Filters shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing of all the production filters in the plant;
    3. Sufficient filter surface area should be provided so that, during any one filtration cycle, no more than two feet of backwash water will accumulate over the sand surface;
    4. The filter shall not be subject to flooding by surface runoff or flood waters. Finished grade elevation shall be designed to facilitate maintenance, cleaning and removal of surface sand as required;
    5. The filter media shall consist of a minimum of twelve inches of sand, three to four inches of supporting small gravel or torpedo sand and nine inches of gravel in graded layers. All sand and gravel shall be washed to remove fines;
    6. Unless the design engineer submits information justifying different sand sizes, filter sand shall have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5;
    7. Each filter shall be provided with an adequate under drain system to permit satisfactory discharge of filtrate;
    8. Provision shall be made for the sampling of each filter effluent;
    9. Overflow devices from the filters shall not be permitted;
    10. Where freezing is a problem provisions should be made for covering the filters during winter months;
    11. Filters shall not have a common wall with a compartment storing finished water but shall be separate structures. Filter piping shall not create an unprotected cross-connection; and
    12. The provisions for the final disposal of the residuals shall be provided in the submittals to the department and the equipment or contractor arrangements necessary to remove and haul the sludge shall be specified.

b. Lagoons may be used to temporarily store residuals until they can be removed for final disposal. Lagoons shall have the following features:
    1. Be designed with a volume 10 times the total quantity of wash water discharged during any 24-hour period;
    2. A minimum usable depth of five feet;
    3. Length four times width and the width at least three times the depth, as measured at the operating water level;
    4. Outlet to be at the end opposite the inlet;
    5. Velocity to be dissipated at the inlet end; and

6. The provisions for the final disposal of the residuals shall be provided in the submittals to the department and the methods and equipment necessary to remove and haul the residuals shall be specified.

c. Discharge to community sanitary sewer
Iron and manganese residuals and wastewater can be discharged to a permitted community sanitary sewer. If the wastewater treatment facilities are designed to remove and process the residuals. Because the residuals are not biodegradable and will settle and interfere with their operation, the department will not approve discharging residuals to systems using wastewater stabilization ponds or to wastewater plants using mechanical treatment unless they have facilities to remove the residuals before the biological treatment processes. The following must be done to obtain an approval to discharge process residuals to a sanitary sewer system:
   1. Obtain a letter of approval from the owner or operating authority of the sewerage system and submit a copy to the department;
   2. Submit an engineering report explaining the impact of the residuals on the wastewater treatment facility and its sludge drying and handling facilities;
   3. Submit evidence that the wastewater collection system, the wastewater treatment facilities and the sludge handling facilities are capable of handling the additional hydraulic and solids loading; and
   4. A holding basin for controlled discharge may be required**.**

d. Recycling Iron and manganese wastewater
Recycling of supernatant or filtrate from iron and manganese waste treatment facilities to the head of an iron removal plant shall not be allowed.

4.11.7. Filter Backwash Water

a. May be discharged directly to a sanitary sewer under the following conditions.
   1. Approval from the owner or operating authority of the sewerage system must be obtained and proof of the approval must be submitted.
   2. The wastewater collection system and the wastewater treatment facilities must be capable of handling the hydraulic loading and evidence must be submitted to assure this.
   3. A holding basin for controlled discharge may be required.

b. Discharge to the waters of the state**.**
The waste wash water shall be treated to remove solids and chlorine residuals. Solids may be removed by gravity using a holding basin or lagoon. If sufficient holding time is provided, holding the wash water in a lagoon may allow the chlorine residual to be used up with no further treatment. Otherwise facilities must be provided to remove the chlorine residuals. Holding basins or lagoons shall have the following:

1. discharge structures that have sluice gates or valves to easily control the discharge;
2. a design that allows a dechlorinating chemical to be fed;
3. a minimum volume of three times the total quantity of wash water expected to be discharged during any 24-hour period;
4. a minimum water depth of three feet;
5. a length four times width and the width a least three times the depth as measured at the operating water level;
6. an outlet at the end opposite the inlet; and
7. Velocity to be dissipated at the inlet end.

c. Recycling waste filter wash water and filter to waste water to the head of the treatment plant may be considered. Plants treating surface water or groundwater under the influence of surface water should not recycle waste filter wash water.
   1. Holding basins or lagoons shall be sized to ensure that cleaning of other filters will not be delayed because of a full holding basin or lagoon. Unless the engineer can justify the use of other criteria, a holding basin or lagoon shall have a volume ten times the total quantity of wash water and filter to waste water required to clean one filter. Unless the engineer can justify the use of other criteria, a filter backwash shall be calculated at 20 gallons per minute per square foot for 15-minutes and filter to waste shall be calculated at 3 gallons per minute per square foot for 60-minutes.
   2. The holding basin or lagoon shall not receive discharges from sanitary facilities (water closets, urinals, lavatories, floor drains, sinks, etc.)
   3. Rate of recycling shall not exceed 10 percent of the raw water flow entering the plant regardless of the designed plant capacity.
   4. To determine the rate of flow, a meter shall be provided in the recycle piping. The meter shall have a remote readout located in the plant operations area that reads rate of flow in gallons per minute.
   5. To control rate of flow, a throttling valve or similar device shall be provided in the recycle piping.
   6. Filter backwash shall not be recycled when it contains excessive algae, iron, manganese or other contaminants; when finished water taste and odor or colored water problems are encountered or when it may cause disinfection byproduct levels in the distribution system to exceed allowable levels.

4.11.8. Wastes from Plants using Missouri or Mississippi River Water

The Missouri Clean Water Commission regulation 10 CSR 20-7.015(2) states that the suspended solids that are present in the water and are removed during treatment and any additional suspended solids resulting from the treatment of the water may be discharged to the Missouri River or the Mississippi River if the raw water source is:

a. Missouri River or Mississippi River waters.
b. Alluvial wells along the banks of the Missouri River or Mississippi River.

Chapter 5 -- Chemical Application

5.0 General.

No chemicals shall be applied to treat drinking water unless specifically permitted by the department. All chemicals used to treat drinking water shall be certified for drinking water use in accordance with ANSI/NSF Standard 60/61.

5.0.1. Plans and specifications.

Plans and specifications shall be submitted for review and approval, as provided for in Chapter 5 of this document. Because specifications for chemical feeding equipment are generally performance specifications that give feed ranges and generic descriptions, detailed manufacturers' information on the equipment actually installed must be provided to obtain the required Final Construction Approval from the department. Plans and specifications shall include:

a. Descriptions of feed equipment, including maximum and minimum feed ranges;
b. Location of feeders, piping layout and points of application;
c. Storage and handling facilities;
d. Specific chemicals to be used;
e. Operating and control procedures including proposed application rates and the results of chemical analyses, historic dosages, and the basis for choosing the proposed application rates, provided in the engineering report or as an appendix to the specifications; and
f. Description of testing equipment.

5.0.2. Chemical application.

Chemicals shall be applied to the water at such points and by such means to:

1. Ensure maximum efficiency of treatment;
2. Ensure maximum safety to consumer;
3. Provide maximum safety to plant personnel;
4. Ensure satisfactory mixing of the chemicals with the water;
5. Provide maximum flexibility of operation through various points of application, when appropriate;
6. Prevent backflow or backsiphonage between multiple points of feed through common manifolds;
7. Prevent any spillage of chemical into the mixing basin or settling basin. When chemical storage or feeders are located on top of the mixing and/or settling basin, a 4-inch to 6-inch curb shall be constructed around all the basin openings. Chemical feed or storage facilities shall not be located on top of pumping wells, transfer wells or clearwells unless specifically approved by the department; and
8. Minimize interference and undesirable reactions between chemicals.

5.0.3. General equipment design.

General equipment design shall be such that:

a. Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate throughout the range of feed;
b. Chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution;
c. Corrosive chemicals are introduced in such a manner as to minimize potential for corrosion and damage to water piping, treatment basins, and the water treatment facilities**;**
d. Chemicals that are incompatible are not fed, stored, or handled together;
e. All chemicals are conducted from the feeder to the point of application in separate conduits;
f. Chemical feeders are as near as practical to the feed point;
g. Chemical feeders and pumps operate at no lower than 20 percent of the feed range;
h. Chemicals are fed by gravity where practical; and
i. Adequate space is provided around each chemical feeder to safely load, operate, clean, and maintain each feeder.

5.1. FACILITY DESIGN.

5.1.1. Number of feeders.

a. Where chemical feed is necessary for the production of safe drinking water, such as chlorination, coagulation, or other essential processes:
   1. A minimum of two feeders shall be provided or a standby unit or a combination of units of sufficient capacity shall be available to replace the largest unit during shut-downs; and
   2. Where a booster pump or a transfer pump is required, duplicate equipment shall be provided and, when necessary, standby power.
b. A separate feeder shall be used for each chemical applied and should be used for each application point. Only one solution pump should draw from a solution tank, day tank, barrel, or carboy.
c. Spare parts shall be available for all feeders to replace parts that are subject to wear and damage.

5.1.2. Control.

a. Feeders may be manually or automatically controlled. Automatic controls shall be designed to allow override by manual controls and to allow adjustment of each control parameter.
b. When automatic controls are used, they shall include devices that prevent feeders from operating unless water is being produced**.**
c. When automatic controls are used, they shall include devices so that chemical feed rates shall be proportional to flow.

d. A means to measure all appropriate water flows must be provided in order to determine chemical feed rates.
e. Provision shall be made for measuring the volume or weight of chemicals used.
f. Weighing scales:
    1. Shall be provided for weighing all active gas cylinders at all plants utilizing chlorine gas, carbon dioxide, or ammonia gas. Scales for weighing all gas cylinders smaller than one ton in size shall be low profile for ease in manually loading cylinders onto the scales. Otherwise, electric hoists, hoist tracks, and properly sized cylinder clamps shall be provided;
    2. May be required for fluoride solution feed;
    3. Shall be provided for each active chemical solution day tank;
    4. Shall be provided for each solution or emulsion fed from carboys or barrels;
    5. Shall be provided to weigh chemicals when making batches of chemical feed solutions**;**
    6. Should be provided for volumetric dry chemical feeders;
    7. Should be accurate to measure increments of 0.5 per cent of load; and
    8. Totaling gas meters shall be provided to measure all gas chemicals fed from rail cars or bulk storage containers.

5.1.3. Dry chemical feeders.

Dry chemical feeders shall:

a. Measure chemicals volumetrically or gravimetrically;
b. Provide adequate solution water and agitation of the chemical in the solution pot;
c. Provide gravity feed from solution pots where possible;
d. Completely enclose chemicals to prevent emission of dust to the operating room;
e**.** Be located and designed to prevent lifting injuries when loading sacks of chemical into the feeder. The current OSHA or National Institute of Occupational Safety and Health (NIOSH) guidance for manual lifting should be followed;
f. Provide adequate space around each feeder to allow chemical pallets to be moved close to the feeder and minimize the distance that chemical bags or containers must be carried;
g. Have chemical hoppers sized to minimize loading frequencies to no more than once per eight-hour shift;
h. Not have bulk storage facilities that feed directly into the feed chamber but have a chemical hopper on the feeder that is large enough to minimize chemical fluidization;
i. Have vibrators and anti-bridging and caking equipment that is separate from those provided on the bulk storage facilities;
j. Have feeder shells and housings constructed of stainless steel, aluminum or a nonmetallic substance that fully enclose the chemical being fed to

minimize chemical dust created by the feeding process;

k. Have solution tanks that are sized according to the amount of chemical to be fed. Undersized or oversized solution tanks shall be avoided; and
l. Have rate-of-flow meters on each solution-tank water line to control the amount of solution water going to dry feeder solution tanks.

5.1.4. Positive displacement solution pumps.

a. Positive displacement type solution feed pumps should be used to feed liquid chemicals, but should not be used to feed chemical slurries.
b. Bypass piping or other methods for accurately measuring the output of the chemical solution feeders shall be provided.
c. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.

5.1.5. Liquid chemical feeders - Siphon control.

Liquid chemical feeders shall be such that chemical solutions cannot be siphoned into the water supply. Liquid chemical feeders shall:

a. Assure discharge at a point of positive pressure;
b. Provide vacuum relief;
c. Provide a suitable air gap; or
d. Provide diaphragm anti-siphon devices that are spring-loaded in the closed position on the discharge side of each metering pump head or other suitable means or combinations as necessary. When metering pump anti-siphon devices are provided, they should be selected to provide the backpressure required by the pump manufacturer.

5.1.6. Backflow Prevention.

a. A reduced pressure principle backflow prevention assembly shall be provided on the service line supplying water to the water treatment plant according to the requirements of 10 CSR 60-11.010.
b. Backflow prevention shall be provided to ensure that the service water lines discharging to solution tanks shall be properly protected from backflow.
    1. Air gap separation shall be two times the pipe diameter of the water line serving any chemical solution tank.
    2. Atmospheric vacuum breakers conforming to the American Society of Sanitary Engineering (ASSE) standard #1001, shall be applied to water lines serving chemical solution tanks where no shut off or control valves are located downstream of the vacuum breaker.
    3. Pressure vacuum breakers conforming to ASSE standard #1020 shall be applied to water lines serving chemical solution tanks where shut off or control valves are located downstream of the vacuum breaker.
c. No direct connection shall exist between any sewer and a drain or overflow from a feeder, solution chamber or tank. All drains shall end at

least six inches or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

5.1.7. Chemical feed equipment location.

Unless otherwise approved by the department chemical feed equipment shall:

a. Be located in a properly vented separate room(s) to reduce hazards and dust problems;
b. Be conveniently located near points of application to minimize length of feed lines;
c. Be readily accessible for servicing, repair and observing operation;
d. Be located so as to provide feeding by gravity;
e. Be located in a well-lighted area such that additional lighting is not required for normal operation and maintenance;
f. Be located in areas provided with the drains, sumps, finished water plumbing and the hose bibs and hoses necessary to fill solution tanks, clean up spills, and wash equipment;
g. Be located in areas that have floors and walls constructed of material that is suitable to the chemicals being stored and that is capable of being washed; and
h. Be located in areas with floor surfaces that are smooth and impervious, slip-resistant, and well drained with three inches per ten feet minimum slope.

5.1.8. Service water supply.

a. The quality of service water supplied to a treatment facility shall be compatible with the purposes for which it is used. Generally, only potable water should be used. Any proposal to use non-potable plant service water shall be submitted to and approved by the department before construction. When potable water is not used, the hose bibs and all water lines carrying non-potable water shall be clearly labeled. No cross-connection between potable and non-potable water lines is allowed.
b. The amount of solution water used to operate the feeders in a plant should be kept to the minimum necessary. This is especially important in small water treatment facilities. When specifying chemical feeders, the amount of service water required to operate the feeder must be considered.
c. Service water supply shall be:
    1. Ample in supply and adequate in pressure;
    2. Provided with a totaling water meter to determine the amount of water used by the plant;
    3. Properly treated for hardness, when necessary; and
    4. Properly protected against backflow.

5.1.9. Storage of chemicals

a. Space shall be provided for:

1. At least 30 days of chemical supply;
2. Convenient and efficient handling and rotating of chemicals;
3. Dry storage conditions; and
4. A minimum storage volume of 1 1/2 truckloads where bulk purchase is by truck load lots.

b. Chemical storage areas shall be provided with the drains, sumps, finished water plumbing and the hose bibs and hoses necessary to clean up spills and to wash equipment.

c. Chemical storage areas shall have floors and walls constructed of material that is suitable to the chemicals being stored and that is capable of being cleaned.

d. Chemical storage areas shall be well lighted and heated if liquid chemicals are stored.

e. Floor surfaces shall be smooth and impervious, slip-resistant and well drained with three inches per ten feet minimum slope.

f. Vents from feeders, storage facilities, and equipment exhaust shall discharge to the outside atmosphere above grade and remote from air intakes.

g. Storage tanks and pipelines for liquid chemicals shall be specific to the chemicals and not for alternates.

h. Chemicals shall be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved covered storage unit.

i. Bulk liquid chemical-storage tanks must:
1. Be constructed of material compatible with the chemical being stored;
2. Have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, site tubes or a gauge rod extending above a reference point at the top of the tank, attached to a float, or other approved means may be used;
3. Have an overflow that is located where noticeable and a receiving basin or drain capable of receiving accidental spills or overflows;
4. Have an overflow line with a free fall discharge that is directed to minimize splashing and damage to the surrounding area;
5. Have chemical fill lines located for ease in connecting to supply trucks and filling. Side-filling bulk liquid trucks are the most common so driveways and fill line locations should be designed for this type of truck. Lengthy fill lines should be avoided;
6. Have chemical fill lines clearly labeled with the name of the chemical contained by the tank they serve. One set of labels should be located where the chemical supply trucks connect to the chemical fill lines;
7. Be vented to the outside above grade and remote from air intakes with vents constructed of material compatible with the chemical being vented and screened to prevent insects from building nests that may plug the vent;
8. Have vents and overflows sized to handle the chemical and air flow occurring during tank filling and discharging;

9. Have a valved drain, protected against backflow;
10. Be housed in a heated building or the tank and its chemical lines and transfer pumps otherwise protected from freezing; and
11. Be clearly labeled with the name of the chemical stored.

j. Full spill containment should be provided for all bulk storage tanks and shall be provided for some specific chemicals.

5.1.10. Solution tanks.

a. A means, which is consistent with the nature of the chemical solution, shall be provided in a solution tank to maintain a uniform strength of solution. Continuous agitation shall be provided to keep slurries in suspension.
b. Two solution tanks of adequate volume may be required for a chemical to assure continuity of supply in servicing a solution tank. When chemical solutions are mixed and fed in a batch process, solution tanks should be sized to minimize the filling frequency to no more than once per day.
c. Means shall be provided to measure the solution level in the tank.
d. Chemical solutions shall be kept covered. Large tanks with access openings shall have such openings curbed and fitted with tight overhanging covers.
e. Subsurface locations for solution tanks shall:
   1. Be free from sources of possible contamination; and
   2. Assure positive drainage for ground waters, accumulated water, chemical spills and overflows.
f. Overflow pipes, when provided, should:
   1. Be turned downward, with the end screened;
   2. Have a free fall discharge; and
   3. Be located where noticeable.
g. Acid storage tanks must be vented to the outside atmosphere, but not through vents in common with any other chemical.
h. Each tank should be provided with a valved drain, protected against backflow in accordance with paragraphs 5.2.5. and 6. of this document.
i. Solution tanks shall be located and protective curbing provided so that chemicals from equipment failure, spillage or accidental drainage shall not enter the water in conduits, treatment or storage basins.
j. Solution tanks shall be clearly labeled with the name of the chemical contained.

5.1.11. Day tanks.

a. Day tanks shall be provided where bulk storage of liquid chemical is provided.
b. Day tanks shall meet all the requirements of paragraph 5.2.10. of this document.
c. Day tanks should hold no more than a seven-day supply.
d. Day tanks shall be scale-mounted.

e. Hand pumps shall be provided for transfer of acids, caustic solutions or other hazardous chemicals from a carboy or drum into a day tank. For non-hazardous chemicals, a tip rack may be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided, a liquid level limit switch and an over-flow from the day tank must be provided. The over-flow from the day tank must drain by gravity back into the bulk storage tank or to a receiving basin or drain capable of receiving accidental spills or overflows.
f. A means that is consistent with the nature of the chemical solution shall be provided to maintain uniform strength of solution in a day tank. Continuous agitation shall be provided to maintain chemical slurries in suspension.
g. Tanks shall be properly labeled to designate the chemical contained.
h. Motor driven transfer pumps from bulk storage tanks shall be constructed and specified to handle the specific chemical being pumped.
i. Motor driven transfer pumps from bulk storage tanks shall be sized so they can fill the day tank while chemical is fed at the maximum output of the chemical feeder(s) pulling from the day tank. Under these conditions, the transfer pump(s) should be capable of filling the day tank in an hour.
j. Motor driven transfer pumps from bulk storage tanks shall be provided with discharge and suction valves located to allow the pump to be removed for maintenance without draining chemical from the lines to the bulk or day tank.

5.1.12. Chemical Feed lines.

a. All chemical feed lines should be as short as possible in length of run and should be straight.
b. Chemical solution lines:
   1. Should feed by gravity, where possible;
   2. Shall be of durable, corrosion resistant material that is compatible with the specific chemical being fed;
   3. Shall be easily accessible throughout the entire length;
   4 Shall be protected against freezing;
   5. Shall be adequately supported to prevent excessive movement and low areas where chemical will accumulate; and
   6. Shall be constructed to minimize plugging and to facilitate cleaning.
c. Chemical feed lines should slope upward from the chemical source to the feeder when conveying gases.
d. Chemical feed lines shall be designed consistent with scale-forming or solids-depositing properties of the water, chemical, solution, or mixture conveyed and shall be compatible with the chemical being fed.
e. Chemical feed lines should be color-coded, placarded, or otherwise clearly labeled with the name of the chemical contained. (See section 2.14. of this document).
f. Chemical feed lines shall be located so that plant operators do not have to routinely climb over them to get to other operating areas in the plant even

if stiles or stairways are built over feed lines.

g. Chemical feed lines shall be located so that operators do not have to routinely walk under lines carrying strong corrosive, caustic or acid solutions.

5.1.13. Pumping of Chemicals.

When feeding of chemicals by gravity cannot be attained, pumping of chemicals to the different points of application may be considered. The chemical feed pumping system shall provide:

a. Standby pumping;
b. Spare chemical feed line for each chemical;
c. Minimum velocity of 4 feet per second through chemical feed lines;
d. For pigging chemical feed lines and baskets for catching pigs;
e. Water for flushing the chemical feed lines. The waterline must be protected from back-siphonage;
f. Discharge and suction valves located to allow each pump to be removed for maintenance or a means to safely drain the lines prior to disconnection for repairs;
g. Pumps constructed from material that is compatible with the specific chemical being pumped and that are easy to access, disassemble, and maintain;
h. Pumps that are located so that they are not tripping or fall hazards and so that they or their motors are not subject to damage by chemical spilled during routine loading and operation of solution tanks or feeders; and
i. Encasement conduits for underground feed lines for easy removal and maintenance.

5.1.14. Handling.

a. Carts, elevators, and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.
b. Provisions shall be made for disposing of empty bags, drums, or barrels by an approved procedure that will minimize exposure to dusts.
c. Provision shall be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers, in such a way as to minimize dust. Control should be provided by use of:
    1. Vacuum pneumatic equipment or closed conveyor or elevator systems;
    2. Facilities for emptying shipping containers in special enclosures; or
    3. Exhaust fans and dust filters that put the hoppers or bins under negative pressure.
d. Provision shall be made for measuring quantities of chemicals used to prepare feed solutions.

5.2. Chemicals.

5.2.1 Shipping containers.

Chemical shipping containers shall be fully labeled to include chemical name, purity, and concentration and supplier names and addresses.

5.2.2 Assay.

Provisions may be required for assay of chemicals delivered.

5.3. Operator Safety.

5.3.1 Ventilation.

Special provisions shall be made for ventilation of chlorine, chlorine dioxide, anhydrous ammonia and ozone generation, and feed and storage rooms.

5.3.2. Respiratory protection equipment.

a. Respiratory protection equipment meeting the requirements of NIOSH shall be available for each chemical dust, vapor, or gas that may be encountered at a treatment plant. This respiratory protection equipment shall be stored at a convenient location, but not inside any room where the particular chemical is used or stored.
b. Self contained breathing apparatus units shall use compressed air, have at least a 30 minute capacity, have full face masks, and be compatible with units used by the fire department responsible for the plant.

5.4. Specific Chemicals.

Chemical storage handling and feeding facilities for the chemicals specified here shall meet all of the appropriate general requirements of this document and the chemical-specific requirements specified in this chapter.

5.4.1. Chlorine gas.

a. Chlorine gas feed and storage shall be enclosed and separated from other operating areas. The chlorine room or building shall be:
    1. Constructed of fire and corrosion resistant material;
    2. Provided with a shatter-resistant inspection window installed in an interior wall for chlorine rooms;
    3. Orientated so that the feeder settings and scale readings can be easily read from the inspection window and eliminate the need to frequently enter the room or building;
    4. Constructed in such a manner that all openings in a chlorine building or between the chlorine room and the remainder of the plant are sealed. These seals must be capable of withstanding the pressures expected from expanding chlorine gas. Areas sealed shall include, but not be limited to, electrical conduit, switches, lights and receptacles,

ducts, wall, and ceiling and floor joints. Floor drains are not recommended; however, where installed, they shall be plugged or sealed. All holes through the walls, ceiling and floor shall be sealed around where pipes conduits, wires, brackets, fixtures, etc., pass. All chlorine building or room doors shall be designed and fitted to contain chlorine gas leaks inside the room or building.

5. Provided with doors equipped with panic bars assuring ready means of exit and opening only to the building exterior;
6. Provided with doors that lock to prevent unauthorized access but do not need a key to exit the locked room using the panic bars**;**
7. Well lighted with lights that are sealed so that they will continue working during a chlorine leak;
8. Sized to allow the safe maneuvering of gas cylinders using hand trucks or electric hoists; and
9. If free-standing, located down grade from the water treatment plant.

b. Full and empty cylinders of chlorine gas shall be:
   1. Housed in the chlorine storage building or feed or storage room(s)
   2. Restrained in position to prevent upset or rolling,
   3. Stored separate from ammonia, ammonium hydroxide, paint thinner, solvent and petroleum product storage; and
   4. Stored in areas not in direct sunlight or exposed to excessive heat.

c. Where chlorine gas is used, the building or room shall be constructed to provide the following:
   1. Each room or building shall have a ventilating fan or fans with a capacity that provides one complete air change per minute when the room is occupied. The fans shall be constructed of chemical resistant materials and have chemical proof motors. Squirrel cage type fans located outside the chlorine room(s) may be approved if their fan housings and ducting are airtight and made of chlorine and corrosion resistant material;
   2. The ventilating fan(s) shall take suction near the floor as far as practical from the door and air inlet, with the point of discharge located remote from the entrance door to the chlorine room and so that exhausted chlorine gas will not enter any other parts of the water plant or other buildings**,** rooms or structures. Wall fans located in or beside the entrance doors to chlorine feed or storage room shall not be allowed;
   3. Air inlets shall be from the outside the building and be through louvers near the ceiling. These inlet louvers shall seal tightly. Motor operated louvers shall be provided with chlorine and corrosion resistant motor controls and electric connections;
   4. Separate switches for fans and lights shall be outside of the room and beside the entrance door and the interior inspection window. These switches shall be clearly labeled as to what they operate. A signal light indicating fan operation should be provided; and
   5. Vents from feeders and storage containers shall discharge to the

outside atmosphere, above grade and be screened to prevent insects from nesting in and plugging the vents.

d. Heating equipment for chlorinator rooms shall be capable of maintaining a minimum temperature of 60^{o}F and protected from excessive heat. Cylinders and gas lines should be maintained at the same temperature of the feed equipment. Heating or air conditioning equipment provided shall be separate from central heating and air conditioning systems to prevent chlorine gas from escaping. Central heating or cooling ducts shall not terminate in or pass through a chlorine room.

e. Pressure chlorine feed lines shall not carry chlorine gas beyond the chlorinator room. Chlorine gas feed systems that are under a vacuum from the gas cylinder valve out are preferred**.**

f. Sufficient chlorine gas manifolds, cylinder valves, piping and other equipment shall be provided to connect enough chlorine storage containers to a feeder or feeders so as to not exceed the dependable continuous discharge rate of any chlorine gas container. Circulating fans shall not be used to prevent frosting of containers or freezing of feed lines or to increase discharge rates. The normal dependable continuous discharge rate from a 150-lb or 100-lb chlorine gas cylinder is 1¾ pounds per hour at 70 °F and a 35 psi backpressure.

g. Chlorine gas leak detection and control.
    1. A bottle of ammonium hydroxide, 56 percent ammonia solution, shall be available for chlorine leak detection.
    2. Where ton or larger containers are used, at least one atmospheric chlorine gas detector shall be provided in each chlorine storage and feed room. Atmospheric chlorine-gas detectors shall be continuous leak-detection equipment and shall be provided with both an audible alarm and a warning light. Continuous leak-detection equipment should be provided for systems using 150-lb or smaller cylinders.
    3. Where ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided.
    4. Valves should be provided that will automatically shut off all active chlorine-gas cylinders during a leak.
        1. These valves shall be mounted on the chlorine-gas cylinder valves and shall be capable of rapidly shutting off a cylinder even during a power failure.
        2. The valves and all other parts of the automatic system shall be constructed of or encased in chlorine compatible and corrosion resistant material
        3. Operation of the valves shall be controlled by a signal from an atmospheric chlorine gas detector or control room.
        4. A manual shut-off switch shall be provided that also acts as a test switch to provide a full cycle test of the valve actuator.
        5. Audible alarms and warning lights shall be provided indicating when a gas leak and valve shut down has occurred.
        6. Running lights shall be provided to indicate whether a valve is

closed or open.

h. Chlorination equipment.
   1. Type. Solution-feed gas chlorinators or hypochlorite feeders of the positive displacement type must be provided for feeding the chlorine compounds, and ozonation equipment as specified for feeding ozone.
   2. Capacity. The chlorinator capacity shall be such that a free chlorine residual of at least 2 milligrams per liter can be maintained in the water after the required chlorine contact time even when maximum flow rate coincides with anticipated maximum chlorine demand. The equipment shall be of such design that it will operate accurately over the desired feeding range.
   3. Standby equipment. Where chlorination is required for protection of the supply, standby equipment of sufficient capacity shall be available to replace the largest unit. Spare parts shall be made available to replace parts subject to wear and breakage.
   4. Automatic switchover. Automatic switchover of chlorine cylinders should be provided, where necessary, to assure continuous disinfection.
   5. Automatic proportioning. Automatic proportioning chlorinators will be required where the rate of flow or chlorine demand is not reasonably constant.
   6. Eductor. Each eductor must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector water flow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.
   7. Injector/diffuser. The chlorine solution injector/diffuser must be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point.

i. Chlorinator piping.
   1. Cross connection protection. The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre-and post-chlorination systems must be independent to prevent possible siphoning of partially treated water into the clearwell. The water supply to each eductor shall have a separate shut-off valve. No master shut-off valve will be allowed.
   2. Pipe material. The pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

5.4.2. Acids.

a. Acids shall be kept in closed acid-resistant shipping containers or storage units.
b. Acids shall not be handled in open vessels, but shall be pumped in undiluted form from original containers through a suitable piping to the point of treatment or to a tightly sealed, vented and covered day tank.
c. To reduce the hazard to the water plant, acids shall not be diluted. Instead, the metering pumps specified shall permit the use of undiluted acid for installations of any size.

5.4.3. Chlorine Dioxide.

a. Sodium chlorite and sodium chlorate solutions and acids used to generate chlorine dioxide shall not be stored in a chlorine feed or storage room or in any area that may be affected by a chlorine gas leak or by vapors from chlorine compounds.
b. Federal and state rules set plant and distribution system monitoring requirements for systems feeding chlorine dioxide. Thus, the necessary approved analyses equipment, monitoring equipment, and laboratory facilities shall be provided to test for chlorine dioxide and chlorites.
c. Sodium Chlorite and Sodium Chlorate Storage.
    1. The department, before the preparation of final plans and specifications, shall approve proposals for the storage and use of sodium chlorite.
    2. Provision shall be made for proper storage and handling of sodium chlorite to eliminate any danger of fire or explosion associated with its powerful oxidizing nature.
    3. Sodium chlorite or chlorate solutions shall be stored by themselves in a cool, dry, fireproof, separate room. Preferably, they should be stored in an outside building detached from the water treatment facility.
    4. Sodium chlorite or chlorate solutions shall be stored away from organic materials because many materials will catch fire and burn violently when in contact with sodium chlorite or chlorate.
    5. Storage shall be away from combustibles and acids.
    6. The storage structures shall be constructed of noncombustible materials.
    7. If the storage structure must be located in an area where a fire may occur, water shall be available to keep the sodium chlorite area cool enough to prevent heat-induced explosive decomposition of the chlorite.
    8. The storage structure shall be provided with a separate, non-combustible, corrosion-resistant ventilation system to capture mist or fumes.
    9. Full spill containment shall be provided. Furthermore, storage facilities shall not be located over plant treatment basins, pumping

wells, transfer wells, or clearwells.

d. Sodium Chlorite and Sodium Chlorate Handling
   1. The design shall provide the drains, sumps, finished water plumbing, hose bibs and hoses necessary to clean up spills and to wash equipment.
   2. An emergency plan of operation should be developed for the clean up of any spillage.
   3. Storage drums must be thoroughly flushed before recycling or disposal.
   4. Protective safety equipment for the operators shall be provided that includes, but may not be limited to, chemical safety goggles, butyl rubber or neoprene gloves, self-contained breathing apparatus and waterproof outer clothing.

e. Sodium Chlorite and Sodium Chlorate Feeders.
   1. Positive displacement feeders shall be provided for feeding the acids and sodium chlorite and chlorate solutions.
   2. Methods for accurately metering or weighing the sodium chlorite and chlorate solutions shall be provided. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.
   3. Tubing for conveying sodium chlorite or chlorine dioxide solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.
   4. Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.
   5. Check valves shall be provided to prevent the backflow of chlorine into sodium chlorite or chlorate lines.
   6. Storage tanks inside buildings, day tanks and unsealed carboys or barrels shall be vented to the outside with a vent approved by the department.
   7. To reduce the hazard to the water plant operators, sodium chlorite and chlorate solutions and the required acids shall not be diluted. Instead, the metering pumps specified shall permit the use of undiluted solutions for installations of any size.

5.4.4. Chloramines.

a. Anhydrous ammonia.
   1. Anhydrous ammonia storage and handling facilities shall be designed to meet OSHA Standard 1910.111.
   2. With rising temperature, ammonia expands rapidly, increasing the internal pressure in vessels and pipes, etc. This shall be considered in the design and operation of ammonia systems
   3. Anhydrous ammonia feeding facilities shall be located in a separate enclosed room that meets all of the requirements of subparagraph 5.5.1.1. of this document for chlorine gas feeding facilities. However, only explosion-proof electric fixtures shall be used in the room.

4. Anhydrous ammonia contact with chlorine or fluorine can create explosive compounds. Therefore, feeding and storage facility design shall consider methods of preventing ammonia or chlorine leaks from coming into contact with either chemical. Furthermore, fluoride-feeding facilities shall not be located in ammonia feeding or storage rooms.

b. Ammonia Solutions.
    1. Storage.
        1. Ammonia solutions shall be kept in tightly closed containers stored in a separate cool, dry, ventilated room and kept from all forms of chlorine, strong acids, most common metals, strong oxidizing agents, aluminum, copper, brass, bronze, chlorite or chlorate solutions, and other incompatible chemicals.
        2. Ammonia solutions shall be protected from direct sunlight.
        3. The storage room shall be provided with a separate, corrosion-resistant ventilation system to capture mist or fumes and vent them to the outside.
        4. Ammonia solution containers may be hazardous when empty since they retain product residues. Therefore, all warnings and precautions listed for the product should be observed for empty containers.
    2. Ammonia Solution Handling.
        1. Ammonia solutions are very toxic to aquatic life and spills may not be drained into some sanitary sewer systems. Therefore, full spill containment shall be provided.
        2. Absorbent pads and the drains, sumps, finished water plumbing, hose bibs, and hoses necessary to clean up spills and to wash equipment shall be provided.
        3. An emergency plan of operation should be developed for the clean up of any spillage.
        4. Provide protective safety equipment for water plant personnel that includes but is not limited to chemical safety goggles, butyl rubber or neoprene gloves, self-contained breathing apparatus and water proof outer clothing.
        5. To reduce the hazard to the water plant personnel, ammonia solutions shall not be diluted. Instead, solution with the correct strength for the amount fed shall be purchased, or the metering pump specified shall permit the use of undiluted solution for water plants of any size.
    3. Ammonia Solution Feeders.
        1. Positive displacement feeders shall be provided for feeding the ammonia solutions.
        2. Methods for accurately metering or weighing the ammonia solutions shall be provided. Graduated measuring chambers should be built into the feeder piping to allow the feeder output to be routinely checked.

3. Tubing for conveying ammonia solutions shall be Type 1 PVC, polyethylene or materials recommended by the manufacturer.
4. Feed lines shall be installed in a manner to prevent formation of gas pockets and shall terminate at a point of positive pressure.
5. Storage tanks and unsealed carboys or barrels shall be vented to the outside with a vent approved by the department.

5.4.5. Carbon dioxide

a. Recarbonation basin design shall provide:
   1. A minimum detention time of twenty minutes,
   2. Two compartments, each with a depth of eight feet, as follows:
      1. A mixing compartment having a detention time of at least three minutes; and
      2. A reaction compartment.

b. If a carbon dioxide solution is added and rapid mixing is provided, total detention time and basin depths may be reduced. However, supporting data for the proposed reductions must be included as a part of the pre-design submittals.

c. Plants generating carbon dioxide from combustion shall have open top, recarbonation tanks in order to dissipate carbon monoxide and carbon dioxide. Special considerations shall be given to building ventilation when open recarbonation tanks are housed in a building.

d. Where liquid carbon dioxide is used, adequate precautions must be taken to prevent carbon dioxide from entering the plant from the feed lines or recarbonation process. Since liquid carbon dioxide is a cryogenic and a compressed gas, the recommendations of the Compressed Gas Association, Inc. shall be followed when specifying storage and feeding facilities.

e. Provisions shall be made for draining recarbonation basins and removing residuals.

5.4.6. Phosphates.

a. Stock phosphate solution must be kept covered and disinfected by carrying approximately ten milligrams per liter free chlorine residual.

b. Phosphates can act as a nutrient for biological growth in water distribution systems. Therefore, disinfection equipment shall be provided that is sufficient to maintain disinfectant residuals throughout the distribution system at levels necessary to control biological growths. Heterotrophic bacteria studies should be done routinely to ensure that biological growths are controlled through out the distribution system.

5.4.7. Powdered activated carbon.

a. Powdered activated carbon feed and storage facilities.
   1. Powdered activated carbon shall be handled as a potentially

combustible material.

2. Powdered activated carbon shall be stored in a building or compartment as nearly fireproof as possible.
3. A separate room shall be provided for carbon feed installations and other chemicals should not be stored in the same compartment.
4. Carbon feeder rooms shall be equipped with explosion-proof electrical outlets, lights and motors.
5. If possible, the feeder drive controls should be located outside the carbon room.
6. The carbon feed room should be large enough to house the carbon feeder and to store all of the powdered carbon present at the plan safely. Thus, the door to the carbon feed and storage room must be large enough to accommodate a loaded pallet of carbon.
7. Access to the carbon room should be from outside the plant to keep carbon from being tracked throughout the water plant.

b. Powdered activated carbon feeding.
   1. Powdered activated carbon should be added as early as possible in the treatment process to provide maximum contact time.
   2. Flexibility to allow the addition of carbon at several points is required.
   3. Powdered activated carbon should not be applied near the point of chlorine application.
   4. The effectiveness of powdered activated carbon depends upon the carbon particles physically contacting the chemicals to be adsorbed. Therefore, flash mixing shall be provided to ensure an even dispersion of the carbon in the water.
   5. The carbon can be added as a pre-mixed slurry or by a dry-feed machine as long as the carbon is properly wetted. However, solution pipe plugging is a constant problem when pumping carbon slurries. Carbon feed design must consider ways to mediate this problem by using wetting cones and eductors, dual headed slurry pumps, etc**.**
   6. Continuous agitation or suspension equipment is necessary to keep the carbon from depositing in the slurry storage tank.
   7. Provision shall be made for adequate dust control by providing exhaust fans and dust filters**.**
   8. Provision shall be made for adding from 0.1 milligram per liter to at least 50 milligrams per liter at the maximum design flow of the treatment facilities.

c. Powdered activated carbon handling.
   1. Operators shall be provided with respiratory protection that meets OSHA regulation 29 CFR 1910.134 for coal dust. More information on the selection and use of respirators can be obtained from the latest issue of NIOSH Respirator Decision Logic.
   2. Additional personal protective equipment to protect skin and eyes should be provided for dry feeder operations and shall be provided for operators that batch make carbon slurries.

5.4.8. Fluoridation

Commercial sodium fluoride, sodium fluorosilicate and fluorosilicic acid shall conform to the appropriate American Water Works Association (AWWA) standards (B-701, B-702, and B-703) to ensure that the drinking water will be safe and potable. The department must approve other fluoride compounds that may be available. The department must approve the proposed method of fluoride application before preparation of final plans and specifications.

a. Fluoride compound storage. Fluoride chemicals should be isolated from other chemicals to prevent contamination. Compounds shall be stored in covered or unopened shipping containers and should be stored inside a building. Adequate ventilation in storage area is necessary. Bags, fiber drums, and steel drums should be stored on pallets. Carboys, day tanks, or inside bulk storage tanks containing fluosilicic acid must be completely sealed and vented to the atmosphere at a point outside any building. Bulk storage tanks for fluorosilicic acid must be provided with secondary containment and shall not be located over plant treatment basins, pumping wells, transfer wells or clearwells. Unsealed storage units for hydrofluosilicic acid shall be vented to the atmosphere at a point outside any building.
b. Chemical feed equipment and methods. Fluoride feed equipment shall meet the following requirements:
    1. The fluoride feed system must be installed so that it cannot operate unless water is being produced (interlocked). For example, the metering pump must be wired electrically in series with the main well pump or the service pump. If a gravity flow situation exits, a flow switch shall be installed.
    2. When the fluoridation system is connected electrically to a well or service pump, it must be made physically impossible to plug the fluoride metering pump into any continuously active ("hot") electrical outlet. The pump shall be plugged only into the circuit containing the interlock protection.
    3. A secondary flow-based control device (e.g., a flow switch or a pressure switch) should be provided as back-up protection.
    4. The fluoride injection point should be located where all the water to be treated passes. However, fluoride should not be injected at sites where substantial losses of fluoride can occur. Fluoride compounds shall not be added before lime-soda softening or ion exchange softening.
    5. The fluoride injection point in a water line should be located in the lower one third of the pipe, and the end of the injection line should extend into the pipe approximately one-third of the diameter of the pipe.
    6. A corporation-stop valve should be used at the fluoride injection point when injecting fluoride under pressure. To protect water plant operators, a safety chain shall be installed in the assembly at the fluoride injection point if a corporation stop valve assembly is used.
    7. Two diaphragm-type antisiphon devices must be installed in the

fluoride feed line when a metering pump is used. These antisiphon devices should have a diaphragm that is spring-loaded in the closed position. One device should be located at the fluoride injection point and one device shall be located at the metering pump head on the discharge side. Metering pump antisiphon devices should be selected to provide the backpressure required by the pump manufacturer.

8. Operation of a fluoridation system without a functional antisiphon device can lead to an overfeed that exceeds 4 mg/L. Therefore, maintenance manuals, tools and repair parts must be provided to the system operators so that all antisiphon devices can be dismantled and visually inspected at least once a year. Schedules of repairs or replacements should be based on the manufacture's recommendations. Equipment for semiannual vacuum testing of all antisiphon devices should be provided.
9. Fluoride metering pumps should be located on a shelf not more than 4 feet (1.2 m) higher than the lowest normal level of liquid in the carboy, day tank, or solution container. A flooded suction line is not recommended in water fluoridation.
10. For greatest accuracy, metering pumps should be sized to feed fluoride near the midpoint of their range. Pumps should always operate between 30%-70% of capacity. Metering pumps that do not meet these size specifications should not be installed. Oversized metering pumps should not be used because serious overfeeds (i.e., an overfeed that exceeds 4 mg/L) can occur if they are set too high. Conversely, undersized metering pumps can cause erratic fluoride levels.
11. Priming switches on the metering pumps shall be spring-loaded to prevent pumps from being started erroneously with switches in the priming position.
12. Flow meter-paced systems should not be installed unless the rate of water flow past the point of fluoride injection varies by more than 20%.
13. A master meter on the water service line must be provided so that calculations can be made to confirm that the proper amounts of fluoride solution are being fed.
14. Fluoride solutions shall not be injected in a point of negative pressure.
15. The fluoride feed line(s) should be either color-coded, when practical, or clearly identified by some other means. Color-coding helps prevent possible errors when taking samples or performing maintenance. The pipes for all fluoride feed lines should be painted light blue with red bands. The word "fluoride" and the direction of the flow should be printed on the pipe or, for small piping, on the wall beside the pipe.
16. The dilution water pipe shall end at least two pipe diameters above the highest water level in the solution tank, or an adequate backflow prevention device must be provided. All hose connections within reach of the fluoride feed equipment should be provided with a hose-bib vacuum breaker.

17. Cross-connection controls must be provided that conforms to state regulations in 10 CSR 60-11.010.
18. Hose bibs and water supply piping to supply potable water for clean up of spills shall be provided in both the chemical feed and storage areas. The number of hose bibs and their location depend upon the size of the areas served.

c. Sodium Fluoride Saturator Systems. Sodium fluoride systems are not recommended but may be considered on a case-by-case basis with the department's written approval**.**
d. Fluorosilicic Acid Systems.
   1. To reduce the hazard to the water plant operator, fluorosilicic acid (hydrofluosilicic acid) must not be diluted. Instead, the metering pump specified shall permit the use of undiluted fluorosilicic acid for water plants of any size.
   2. No more than a 30-hour supply of fluorosilicic acid should be connected at any time to the suction side of the chemical feed pump. All systems using bulk storage tanks must have a day tank.
   3. Day tanks or direct acid-feed carboys/drums shall be located on scales; daily weights shall be measured and recorded. Volumetric measurements, such as marking the side of the day tank, are not adequate for monitoring acid feed systems.
   4. Full spill containment shall be provided for bulk storage tanks. Furthermore, bulk storage facilities cannot be located over plant treatment basins, pumping wells, transfer wells or clearwells.
   5. Bulk storage tanks inside buildings; day tanks and unsealed carboys shall be vented to the outside with a vent approved by the department.
e. Dry Fluoride Feed Systems.
   1. Dry feeders (both volumetric and gravimetric) must be provided with a solution tank.
   2. Solution tanks shall be sized according to Water Fluoridation: A Manual for Engineers and Technicians published by the Centers for Disease Control and Prevention.
   3. A mechanical mixer should be used in every solution tank of a dry feeder when sodium fluorosilicate is used.
   4. Scales must be provided for weighing the amount of chemicals used in the dry feeder.
f. Testing Equipment.
   1. Surface water plants should use the ion electrode method of fluoride analysis.
   2. A magnetic stirrer should be used in conjunction with the ion electrode method of fluoride analysis.
   3. The colorimetric method (SPADNS) of fluoride analysis can be used where no interference occurs or where the interferences are consistent (e.g., from iron, chloride, phosphate, sulfate, or color).
g. Secondary controls. Secondary control systems for fluoride chemical feed devices may be required by the department as a means of reducing the

possibility for overfeed.

h. Protective equipment. The use of personal protective equipment (PPE) is required when fluoride compounds are handled or when maintenance on fluoridation equipment is performed. The employer should develop a written program regarding the use of PPE and make this a part of the operation plan for the system. Safety procedures should be routinely followed and enforced.

1. Fluorosilicic acid.

   a. At a minimum, the operator shall be provided with the following personal protective equipment for normal maintenance and operation of fluorosilicic acid facilities:

      i. Gauntlet neoprene gloves with cuffs, which should be a minimum length of 12 inches (30.5 cm);

      ii. Full face shield and splash-proof safety goggles; and

      iii . Heavy-duty, acid-proof neoprene apron or acid-proof clothing and shoes.

   b. Specific procedures for handling leaks in bulk storage tanks must be included in the required, system, emergency operations plan.

   c. A safety shower and an eye wash station must be available and easily accessible.

2. Sodium fluoride or sodium fluorosilicate. An eye wash station should be available and easily accessible. The operator shall be provided with the following personal protective equipment:

   a. A National Institute for Occupational Safety and Health (NIOSH)/Mine Safety and Health Administration (MSHA)-approved, N-series particulate respirator (i.e., chemical mask) with a soft rubber face-to-mask seal and replaceable cartridges (49-51);

   b. Splash-proof safety goggles;

   c. Gauntlet neoprene gloves, which should be a minimum length of inches (30.5 cm); and

   d Heavy-duty, acid-proof neoprene apron.

3. Dust control.

   a. Provision must be made to minimize fluoride dust when transferring dry fluoride compounds from shipping containers to storage bins or hoppers. Feeder hoppers shall be provided with an exhaust fan and dust filter that place the hopper under a negative pressure. Air exhausted from the fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

   b. Provision shall be made for disposing of empty bags, drums, or barrels in a manner that will minimize exposure to fluoride dusts. A floor drain should be provided to facilitate the hosing of floors.

5.5. Ozone

5.5.1. Ozone Generator

a. Capacity.
   1. The production rating of the ozone generators shall be stated in pounds per day and kw-hr per pound at a maximum cooling water temperature and maximum ozone concentration.
   2. The design shall ensure that the minimum concentration of ozone in the generator exit gas will not be less one percent, by weight.
   3. Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time, which can result in premature breakdown of the dielectrics.
   4. The production rate of ozone generators will decrease with a variation in the supply temperature of the coolant throughout the year. Curves or other data shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum temperature.
   5. Appropriate ozone generator backup equipment must be provided.

b. Electrical.
   The generators can be low, medium or high frequency type. Specifications shall require that the transformers, electronic circuitry and other electrical hardware be proven, high quality components designed for ozone service.

c. Cooling. The required water flow to an ozone generator varies with the ozone production. Normally unit design provides a maximum cooling water temperature rise of 2.8°C (5°F). The cooling water must be properly treated to minimize corrosion, scaling and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to ensure proper water conditions are maintained. Where cooling water is treated cross connection control shall be provided to prevent contamination of the potable water supply.

d. Materials. To prevent corrosion, the ozone generator shell and tubes shall be constructed of Type 316L stainless steel**.**

5.5.2. Ozone Contactors.

The selection or design of the contactors and method of ozone application depends on the purpose for which the ozone is being used.

a. Bubble Diffusers. Where disinfection is the primary application, a minimum of two contact chambers, each equipped with baffles to prevent short-circuiting and induce countercurrent flow, shall be provided. Ozone shall be applied using porous-tube or dome diffusers.

b. The minimum contact time shall be ten minutes. A shorter contact time may be approved if justified by appropriate design and CT considerations.

c. For ozone applications in which precipitates are formed , such as with iron and manganese removal, porous diffusers should be used with

caution.

d. Where taste and odor control is of concern, multiple application points and contactors shall be considered.

e. Contactors should separate closed vessels that have no common walls with adjacent rooms. The contactors must be kept under negative pressure and sufficient ozone monitors shall be provided to protect worker safety. Placement of the contactors where the entire roof is exposed to the open atmosphere is recommended. In no case shall the contactor roof be a common wall with a separate room above the contactors.

f. Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 1.5 inches of concrete. Smaller contact vessels can be made of stainless steel, fiberglass or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.

g. Where necessary a system shall be provided between the contactors and the off-gas destruction unit to remove froth from the air and return the other to the contactors or other location acceptable to the reviewing authority. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactors head-space.

h. All openings into the contactors for pipe connections, hatchways, etc. shall be properly sealed using welds or ozone resistant gaskets such as Teflon or Hypalon.

i. Multiple sampling ports shall be provided to enable sampling of each compartment's effluent water and to confirm CT calculations.

j. A pressure/vacuum relief valve shall be provided in the contactors and piped to a location where there will be no damage to the destruction unit.

k. The diffusion system should work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel.

l. The depth of water in bubble diffuser contactors should be a minimum of 18 feet. The contactors should have a minimum of 3 feet of freeboard to allow for foaming.

m. All contactors shall have provisions for cleaning, maintenance and drainage of the contactors. Each contactor compartment shall be equipped with an access hatchway.

n. Aeration diffusers shall be fully serviceable by either cleaning or replacement.

o. Other Contactors. Other contactors, such as the venturi or aspirating turbine mixer contactors, may be approved by the department provided adequate ozone transfer is achieved and the required contact times and residuals can be verified.

5.5.3. Ozone Destruction Unit.

A system for treating the final off-gas from each contactor must be provided in order to meet safety and air quality standards. Acceptable systems include

thermal destruction and thermal/catalytic destruction units. In order to reduce the risk of fires, the use of units that operate at lower temperature is encouraged, especially where high purity oxygen is the feed gas. The maximum allowable ozone concentration in the discharge is 0.1 ppm (by volume). At least two units shall be provided which are each capable of handling the entire gas flow. Exhaust blowers shall be provided in order to draw off-gas from the contactors into the destruction unit. Catalysts must be protected from froth, moisture, and other impurities that may harm the catalyst. The catalyst and heating elements shall be located where they can easily be reached for maintenance.

5.5.4. Piping Materials.

Only low carbon 304L and 316L stainless steels shall be used for ozone service with 316L the preferred.

5.5.5. Joints and Connections.

Connections on piping used for ozone service are to be welded where possible. Connections with meters, valves, or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon or Hypalon. Screwed fittings shall not be used because of their tendency to leak. A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactors to prevent moisture reaching the generator.

5.5.6. Instrumentation.

Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet of the ozone generators and contactors and at the inlet to the ozone destruction unit. Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a certain preset level. Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors shall be used. Air flow meters shall be provided for measuring air flow from the desiccant dryers to each of other ozone generators, air flow to each contactor and purge air flow to the desiccant dryers. Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generators feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water. Water flow meters shall

be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply. Ozone monitors shall be installed to measure ozone concentration in both the feed-gas and off-gas from the contactors and in the off-gas from the destruction unit. For disinfection systems, monitors shall also be provided for monitoring ozone residuals in the water. The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined. A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactors and a minimum of one ambient ozone monitor shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.

5.5.7. Alarms.

The alarm/shutdown systems listed here should be considered at each installation.

a. Dew point shutdown/alarm. This system should shut down the generator in the event the system dew point exceeds-60 °C (-76 °F).
b. Ozone generator cooling water flow shutdown/alarm. This system should shut down the generator in the event that cooling water flows decrease to the point that generator damage could occur.
c. Ozone power supply cooling water flow shutdown/alarm. This system should shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply.
d. Ozone generator cooling water temperature shutdown/alarm. This system should shutdown the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.
e. Ozone power supply cooling water temperature shutdown/alarm. This system should shutdown the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.
f. Ozone generator inlet feed-gas temperature shutdown/alarm. This system should shutdown the generator if the feed-gas temperature is above a preset value.
g. Ambient ozone concentration shutdown/alarm. The alarm should sound when the ozone level in the ambient air exceeds 0.1 ppm or a lower value chosen by the water supplier. Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor.
h. Ozone destruct temperature alarm. The alarm should sound when temperature exceeds a preset value.

5.5.8. Safety.

The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume). Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation. High voltage and high frequency electrical equipment must meet current electrical

and fire codes. Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs. A portable purge air blower that will remove residual ozone in the contactors prior to entry for repair or maintenance should be provided.

5.5.9. Construction Considerations.

Prior to connecting the piping from the desiccant dryers to the ozone generators the air compressors should be used to blow the dust out of the desiccant. The contactors should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactors and checking for pressure losses. Connections on the ozone service line should be tested for leakage using the soap-test method.

5.6. Ozone Feed Gas Preparation

Feed gas can be air, high purity oxygen, or oxygen enriched air. Air handling equipment on conventional low pressure air feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some "package" ozonation systems for small systems may work effectively operating at high pressure without the refrigerant dryer and with a "heat-less" desiccant dryer. In all cases the design engineer must ensure that the maximum dew point of -60°C (-76° F) will not be exceeded at any time. For oxygen-feed systems, dryers typically are not required.

5.6.1. Air Compression.

a. Air compressors shall be of the liquid-ring or rotary lobe, oil-less positive displacement type for smaller systems or dry rotary screw compressors for larger systems.
b. The air compressors shall have the capacity to simultaneously provide for maximum ozone demand, provide the airflow required for purging the desiccant dryers (where required) and allow for standby capacity.
c. Air feed for the compressors shall be drawn from a point protected from rain, condensation, mist, fog, and contaminated air sources to minimize moisture and hydrocarbon content of the air supply.
d. A compressed air after-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.
e. A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a break-down.

5.6.2. Air Drying.

a. Dry, dust free and oil- free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation, and to prevent damage to

the generator dielectrics. Sufficient drying to maximum dew point of -60° C (-76 degrees ° F) must be provided at the end of the drying cycle

b. Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure system, a refrigeration air dryer in series with heat-reactivated desiccant dryer shall be used.

c. A refrigeration dryer capable of reducing inlet air temperature to 4° C (40° F) shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.

d. For heat-reactivated desiccant dryers, the unit shall contain two desiccant filled towers complete with pressure relief valves, two four-way valves and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption style time of 16 hours while operating at the maximum expected moisture loading conditions.

e. Multiple air dryers shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

g. Each dryer shall be capable of venting "dry" gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are "on-line."

5.6.3. Air Filters.

a. Air filters shall be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators.

b. The filter before the desiccant dryers shall be of the coalescing type and be capable of removing aerosol and particulate larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be of the particulate type and be capable of removing all particulate greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

5.6.4. Air Preparation Piping.

Piping in the air preparation system can be common grade steel, seamless copper, stainless steel or galvanized steel. The piping must be designed to withstand the maximum pressures in the air preparation system.

Chapter 6 -- Minimum Construction Requirements for Pumping Facilities

6.0 General

This section applies to community water systems that construct or make major modifications to pumping facilities.

6.01. National Standards.

a. Unless otherwise noted in this document, design and construction of the following components shall be in accordance with the latest edition of the American Water Works Association (AWWA) Standards:
   1. AWWA Standard E101 for Vertical Turbine Pumps-Line Shaft and Submersible Types;
   2. AWWA Standard C500 for Metal Seated Gate Valves for Water Supply Service;
   3. AWWA Standard C509 for Resilient Seated Gate Valves for Water Supply Service;
   4. AWWA Standard C504 for Rubber Seated Butterfly Valves;
   5. AWWA Standard C507 for Ball Valves 6-inch Through 48-inch;
   6. AWWA Standard C508 for Swing-Check Valves for Water Works Service 2-inch Through 24-inch;
   7. AWWA Standard C115 for Flanged Ductile Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges;
   8. AWWA Standard C200 for Steel Water Pipe 6-inch and Larger;
   9. AWWA Standard C206 for Field Welding of Steel Water Pipe;
   10. AWWA Standard C207 for Steel Pipe Flanges for Water Works Services Sizes 4-inch Through 144-inch; and
   11. AWWA Standard C220 for Stainless-Steel Pipe 4-inch and Larger.

b. Centrifugal Pumps.
   Unless otherwise noted in this document, centrifugal pumps shall be designed and constructed in accordance with the latest Hydraulic Institute Standards B73.1 (horizontal types) or B73.2 (vertical types), except that the following requirements shall be observed:
   1. Larger stuffing boxes for mechanical seals shall be used;
   2. Solid Shafts shall be used for close coupled, end suction, horizontal centrifugal pumps to eliminate bending motion caused by the impeller; and
   3. Close coupled, end suction, horizontal centrifugal pumps should not be used if the L^3/D^4 ratio is greater than 60 where L is shaft length and D is shaft diameter.

c. Electrical Equipment.
   Unless otherwise noted in this document, design and construction of all electrical equipment and all wiring associated with pumping facilities shall be in accordance with the latest NFPA 70 National Electric Code

published by the National Fire Protection Association and shall be in accordance with any applicable local electric code or portion of a local electric code that is more stringent than the National Electric Code. In addition, pump motors shall meet applicable requirements of the Federal Energy Policy and Conservation Act and rules of the United States Department of Energy on efficiency requirements of electric motors.

d. Buildings.
Unless otherwise noted in this document, design and construction of buildings that house pumping facilities should be such that the structure will have a NFPA Type I (443) construction rating as outlined in the latest NFPA 270 Standard on Types of Building Construction published by the National Fire Protection Association.

e. Ladders, Stairways, Handrails and other Safety Equipment.
Unless otherwise noted in this document, design and construction of all ladders, stairways, handrails, safety cages, and other safety appurtenances for pumping facilities shall conform to the latest federal Occupation Safety and Health Administration (OSHA) Regulation 29 CFR, Part 1910, Occupational Safety and Health Standards, General Industry Standards. These safety appurtenances shall also conform to any applicable local ordinances, codes, standards or portion thereof that are more stringent than the OSHA standards.

f. Other Pumping Equipment.
Pumps, valves, pipe, and appurtenances other than those listed above in the national standards may be used in pumping facilities provided the engineer demonstrates that the components have sufficient strength, durability, and functionality. Some specialty components not listed in the national standards may be more appropriate, such as stainless steel, nickel-copper alloy or low-zinc bronze bolts for flanged piping to reduce corrosion or globe valves when throttling is needed. In these cases, the most appropriate component is recommended. Solvent welded polyvinylchloride (PVC) pipe shall not be used.

6.02. Other General Standards.

a. Pumping facilities shall be designed to maintain the sanitary quality of the pumped water. No pumping station shall be subject to flooding. Subsurface pits or pump rooms should be avoided.

b. Electrical efficiency of the pumping system should be considered in pump design and overall electrical usage and electrical cost as affected by electrical peak demand considerations should be minimized.

c. Preliminary pump curves and system curves including suction pressures shall be provided as part of a complete hydraulic analysis showing conditions for all possible combinations of pumps in operation. This information shall be provided as part of the plans and specification submittal.

d. As part of the final as-built plans or certification submitted by the engineer

for pumping facilities projects, the department shall be provided with manufacturer, model number, impeller size, horsepower, voltage and amperage requirements for both unsteady state (startup) and steady state conditions, rotational speed(s), electrical phase requirements, pump curve showing both head versus flow characteristics and efficiency characteristics, and life expectancy with proper maintenance for each pump and motor. The department shall also be provided with final cost of the project, excluding land and easement.

6.1. Location.

6.1.1. The pumping station shall be so located that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system, and protection against fire, flood, vandalism, terrorist acts, or other hazards.

6.1.2. Site protection shall include the following:

a. The pumping station shall be elevated to a minimum of four feet above the 100 year return frequency flood elevation or four feet above the highest historical flood elevation, whichever is higher, or protected to such elevations;

b. The pumping station shall be readily accessible to operating and maintenance personnel at all times unless the overall system design allows the station to be out of service for the period of inaccessibility;

c. The area around the pumping station shall be graded to route surface water drainage away from the station; and

6.1.3. Pumping stations shall be protected against vandalism, sabotage, terrorist acts, or entrance by unauthorized personnel. See section 2.5. for specific requirements and recommendations.

6.2. Pumping Stations.

6.2.1. Finished and raw water pumping stations.

a. Both finished and raw water pumping stations shall be designed and constructed to include adequate space for the installation of additional units that may be needed during the next 20 years and adequate space around each unit to allow safe servicing;

b. Buildings should be of durable construction with a life expectancy with proper maintenance of 100 or more years. This shall include structural design to withstand all 100- year return frequency weather related events except a direct hit by a tornado;

c. Buildings shall have outward opening doors;

d. Floors shall be at least six inches above finished grade;

e. Underground structures shall be water-proofed;

f. All floors shall be drained in such a manner that the quality of potable water shall not be endangered. All floors shall slope at least 1:40 vertical to horizontal (3 inches per 10 feet) to a suitable drain;

g. Water from pump gland drainage shall be discharged through a suitable outlet without discharging to the floor;
h. Hose bibs to provide water for cleaning shall be provided; and
i. Smooth nose sample tap constructed of brass, bronze, or stainless steel shall be located on each pump discharge to allow bacterial sampling.

6.2.2. Suction wells.

Suction wells shall be designed and constructed to protect the quality of water pumped including the following:

a. Suction wells shall be water tight;
b. Suction wells shall have floors sloped to permit removal of water and solids;
c. Suction wells shall be covered or otherwise protected against contamination; and
d. Suction wells shall have baffles, adjustable false walls, or other appurtenances necessary to prevent vortexing.

6.2.3. Motor and Pump Installation and Removal.

a. Pump stations shall be designed and constructed to allow the safe, efficient removal and reinstallation of each motor and pump including:
    i. Crane ways, hoist beams with hoists, eyebolts, or other facilities shall be provided for lifting, removing, and reinstalling each equipment item that weighs 50 or more pounds; and
    ii The buildings shall be equipped with openings in floors, roofs, or walls to allow safe, efficient removal and reinstallation of equipment. These openings shall be properly hatched, grated, or doored to protect the building from weather or unauthorized entry when not in use.
b. Maintenance equipment, including a tool board, should be provided.

6.2.4. Stairways/Ladders.

Pump stations shall be equipped with permanent stairways and ladders to allow access to every part of the building that must be entered for operation or maintenance of the equipment. Stairways shall be provided to areas that must be routinely entered.

6.2.5. Heating, Ventilation, Lighting, and Dehumidifying.

Pump stations shall be equipped with heating, ventilation, lighting, and dehumidification for the safe, efficient operation and maintenance of the

equipment and reasonable comfort of the operator including the following:

a. Heating equipment shall be installed in facilities that are manned less than one hour per day to maintain a temperature of 40 degrees Fahrenheit (40º F) or higher during the 100-year return frequency coldest temperature;

b. Heating equipment shall be installed in facilities that are manned one hour per day or more to maintain a temperature of 65 degrees Fahrenheit (65º F) or higher during the 100-year return frequency coldest temperature;

c. Ventilation (and air conditioning if needed) shall be provided that achieves the following:
   1. Inside temperature and outside temperature shall not have a differential of more than 10º F during the 100-year return frequency hottest temperature;
   2. Inside temperature shall be maintained lower then the highest allowable ambient operating temperature for each pump motor, and electrical component;
   3. All rooms, compartments, pits, and enclosures below ground level shall be power vented to provide at least six air changes per hour. Switches to operate the ventilation equipment and lights shall be located at the entrance to the below ground facility and shall be placed to allow these to be operated without entering the facility; and
   4. All rooms, compartments, pits, and enclosures that are subject to accumulation of hydrogen sulfide (H_2S), chlorine gas (Cl_2), radon (Rn), or other hazardous substances shall have air changes sufficient to maintain levels of each hazardous substance below the eight hour daily exposure Occupation Safety and Health Administration (OSHA) limit but in no case less than six air changes per hour; and

d. Lighting shall be provided so that every part of the facility is well lit and all instrument readings and all maintenance and operation can be performed without additional lighting. Light fixtures shall be located where bulbs can be readily changed.

6.2.6. Dehumidification.

Dehumidification should be provided if ventilation is not adequate to prevent condensation that is causing a safety hazard or is damaging equipment or controls.

6.2.7. Manned pumping stations.

Pumping stations that are manned for one hour or more per day shall be equipped with potable water, lavatory, and toilet facilities. Plumbing must be installed so as to prevent contamination of the public water supply and wastes shall be discharged in accordance with regulations in 10 CSR 20.

6.3. Pumps.

6.3.1.

Pumps shall be sized as part of the overall public water supply design to meet maximum day pumping demand, diurnal peak flow, instantaneous peak flow, fire flow (if provided), and minimal flows. At least two pumping units shall be provided and the pumps shall be capable of meeting maximum day pumping demand with the largest capacity pump out of service. When pumping units are required to operate over a broad flow range, a sufficient number of single speed pumps with different flow capabilities or variable speed pumps shall be provided. If single speed pumps are provided, they shall be sized to provide the entire range of flow and to avoid excessively short run cycles. Frequently used single speed pumps should be provided in pairs. Variable speed pumps shall be provided in pairs. Any submittal for variable speed or frequency pumps shall include system curves covering the entire flow range and shall specify the base horsepower and base speed required. All specifications for variable frequency drives shall require fault protection for power circuit components and harmonic distortion protection to protect the drive and power system ahead of the drive. Before any variable speed pump is approved, variable torque curves showing that the pump motor will produce enough torque and volt/frequency/torque curves shall be submitted.

6.3.2.

Public water systems that have pressure planes served by a single tower shall have pumps able to meet all water demands and maintain adequate main pressure while the tower is out of service for maintenance. These pumps shall be equipped with permanent pressure relief devices.

6.3.3. Pumping unit design and construction.

a. Pumps shall have ample capacity to supply the peak demand without dangerous overload. Pumps should be designed to operate in the head/flow range of maximum efficiency.
b. Prime movers driving pumps shall be able to operate against the maximum head.
c. Spare parts and tools needed for routine maintenance and repair of pumps and motors shall be readily available.
d. Control equipment shall have the proper heater and overload protection of the air temperature extremes expected.
e. Pumps that generate 30 pounds per square inch (psi) or more surge pressure during start up or shutdown or which generate surges that result in pressure below 20 per square inch gage (20 psig) anywhere in the distribution system shall be equipped with water hammer/surge protection

devices and these devices shall be designed to reduce surge pressure to less than thirty pounds per square inch (30 psi) and maintain distribution pressure of twenty pounds per square inch gage (20 psig) or more.

6.3.4. Suction Lift.

a. Suction lift should be avoided if possible.
b. Suction lift shall be within allowable limits of the pump and preferably less than 14 feet.
c. Provisions shall be made for priming pumps providing suction lift. Prime water must not be of lesser sanitary quality than the water being pumped. Means shall be provided to prevent back siphonage. When an air operated ejector is used, the screened intake shall draw clean air from a point at least ten feet above the ground or other possible contamination unless the air is filtered by an apparatus approved by the department. Vacuum priming may be used.

6.4. Additional Requirements for Booster Pumps.

In addition to meeting the pump requirements in section 6.3. of this document, booster pumps shall meet the criteria in this section.

6.4.1. Booster pumping station

Each booster pumping station shall contain not less than two pumps with capabilities such that peak demand and fire flow, if provided, can be satisfied with the largest pump out of service. The booster station shall also include equipment such as multiple sets of pumps with different capacities, variable speed pumps, hydropneumatic tanks, or other equipment to meet the full range of flow needed if elevated storage is not provided to stabilize pressure on the portion of the distribution system served;

6.4.2. Booster Pumps Drawing from Storage Tanks

6.4.2.1. Booster pumps drawing from storage tanks.

Booster pumps drawing from storage tanks shall be located and controlled to achieve the following:

a. Pumps will not produce negative pressure in the suction line;
b. All pumps shall be valved and piped so that each pump can be isolated and removed with the remaining pumps in service;
c. Automatic or remote control devices shall have a range between start and cutoff pressure which will prevent excessive cycling; and
d. All booster pumping stations shall contain a totalizing meter.

6.4.2.2. Suction lines.

Suction lines should be buried but shall be protected from freezing temperatures if not buried.

6.4.3. Inline booster pumps

Inline booster pumps are pumps that do not draw water directly from storage.

a. Distribution systems with inline booster pumps shall not cause main pressures to drop below 20 psig in any part of the system delivering water to the booster station.
b. All pumps shall be accessible for servicing and shall be valved and piped so that each pump can be isolated and removed with the remaining pumps in service.

6.4.4. Individual home booster pumps

Individual home booster pumps shall not be allowed for any individual service from the public water supply mains unless approved by the department. Approval will generally be considered only for temporary service until properly designed distribution system improvements can be made to eliminate the low pressure area.

6.4.5. Automatic stations

All automatic stations should be provided with automatic signaling apparatus that will report when the station is out of service. All remote-controlled stations shall be electrically operated and controlled and shall have signaling apparatus of proven performance.

6.5. Appurtenances.

6.5.1. Valves.

a. Pumps shall be adequately valved to permit satisfactory operation, maintenance, and repair of the equipment. If foot valves are necessary, they shall have a net valve area of at least 2½ times the area of the suction pipe and they shall be screened. Each pump shall have a positive-acting check valve on the discharge side between the pump and the shut-off valve.
b. Pressure control valves shall be required for reducing water hammer or surges that equal or exceed 30 pounds per square inch and shall be required if the surge results in pressure below 20 pounds per square inch gage anywhere in the distribution system.

6.5.2. Piping.

In general, piping shall:

a. Be designed so that the friction losses will be minimized;

b. Not be subject to contamination;
c. Have watertight joints;
d. Be protected against surge or water hammer;
e. Be such that each pump has an individual suction line or that the lines shall be so manifolded that they will ensure similar hydraulic and operating conditions;
f. Be equipped with a hose bib for cleaning; and
g. Be equipped with smooth-nose sampling taps constructed of brass, bronze, or stainless steel on both the suction and discharge.

6.5.3. Gauges and meters.

Each pump:

a. Shall have a standard pressure gauge on its discharge line;
b. Shall have a compound gauge on its suction line;
c. Shall have recording gauges in the stations with capacities of 0.5 million gallons per day (MGD) or larger; and
d. Should have a totaling time of operation meter.

6.5.4. Water Seals.

a. Water seals shall not be supplied with water of a lesser sanitary quality than that of the water being pumped.
b. Where pumps are sealed with potable water and are pumping water of lesser sanitary quality, the seal shall:
    1. Be provided with a break tank open to atmospheric pressure;
    2. Have an air gap of at least one inch or two pipe diameters, whichever is greater, between the feeder line and the spill line of the tank; or
    3. Provided with a reduced pressure principle backflow prevention assembly.

6.5.5. Controls.

Pumps, their prime movers, and accessories, shall be controlled in such a manner that they will operate at rated capacity without dangerous overload. Where two or more pumps are installed, provision shall be made for alternating pumps. Provision shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls shall be located above grade.

6.5.6. Power.

For their own protection, all water systems should make an arrangement for back-up power. Systems serving a population of 3,300 or more shall make arrangements for back-up power, and include these arrangements in their emergency operating plan. When power failure would result in

cessation of minimum essential service, power supply should be provided from at least two independent sources or a standby or an auxiliary source should be provided. Portable auxiliary power generators may be used if they are sized to generate sufficient power for normal operation of the pumping station. Pumping stations to be served by portable power generators should be equipped with permanent in-place electric connections and controls for operating on the power generator. Systems with multiple booster pumping stations should have a power supply from at least two independent sources, permanent onsite standby or auxiliary power sources or portable generators for each booster pumping station that serves more than 100 connections.

6.5.7. Water pre-lubrication.

When automatic pre-lubrication of pump bearings is necessary and an auxiliary direct drive power supply is provided, the pre-lubrication line shall be provided with a valved bypass around the automatic control so that the bearings can, if necessary, be lubricated manually before the pump is started, or the pre-lubrication controls shall be wired to the auxiliary power supply.

Chapter 7 -- Min imum Construction Standards for Finished Water Storage Tanks and Reservoirs

7.0. General Design and Construction Standards

7.0.1. AWWA Standards for Unpressurized Tanks and Reserviors

Unless otherwise noted in this rule, unpressurized tanks and reservoirs for finished water storage shall be designed and constructed in accordance with the latest edition of the American Water Works Association (AWWA) standards, as follows:

Welded Steel Tanks for Water Storage	AWWA Standard D100
Coatings for Steel Water Storage Tanks	AWWA Standard D102
Factory Coated Bolted Steel Tanks for Water Storage	AWWA Standard D103
Automatically Controlled Impressed Current Cathodic Protection for the Interior of Steel Water Tanks	AWWA Standard D104
Wire and Strand Wound Circular, Pre-stressed Concrete Water Tanks	AWWA Standard D110
Circular Pre-stressed Concrete Water Tanks with Circumferential Tendons	AWWA Standard D115

7.0.2. Parameters for Unpressurized Tanks and Reservoirs for Finished Water Storage

These parameters should be considered during the design of unpressurized tanks and reservoirs for finished water storage.

a. Tank design should be part of a unified long range, engineering design that includes wells, treatment plants, high service pumps, booster pumps, and distribution mains. Since tanks have an approximate useful life of 50 years, the design should consider future growth, including the elevation of areas likely to be developed during the useful life of the tank. Current service area and future service area should be divided into appropriate pressure zones with operating pressures between 35 psig and 100 psig. All of these items should be reflected in the design to ensure the tank will not become obsolete during its useful life.

b. The tank should be designed to maintain water temperature above 32˚ F during the winter weather that would result in the lowest storage water temperature during a seven-day period taken from the most recent 100-year period of weather data or statistically calculated as a 100-year return frequency. An energy balance should be calculated using the following

parameters: average winter (December, January, February) daily flow into and out of the tank; winter diurnal flow pattern into and out of the tank; water temperature into the tank under the winter design conditions; heat transfer between the water layer and air layer in the tank; heat transfer rate through the tank wall and any insulating layer; heat transfer from the outside tank surface to the atmosphere based on wind speed and air temperature from the winter design conditions; solar energy input to the tank during daylight under the winter design conditions; and radiation heat loss from the tank to the sky during night time under winter design conditions. If winter design conditions are not available, a reasonably conservative estimate can be made using the high and low temperature from the record low temperature day from the nearest U. S. weather station with 100 years of record for one of the seven days, using the average coldest winter day from the nearest U. S. Weather station with 100 years of record for the other six days, using sunrise/sunset times and sun angle for the seven days centered on the winter solstice, using average wind speed for December – February from the nearest U. S. Weather station with 100 years of record, and assuming 50% cloud cover for sky conditions. This energy balance should be used to set the winter tank turnover rate, winter pump ON/pump OFF elevations, inlet and outlet designs to ensure mixing to minimize ice formation, insulation requirements (if appropriate) and heater requirements (if appropriate).

c. The tank should be designed to turn over a sufficient percentage of the stored water daily to minimize aesthetic water quality problems. This percentage may vary with local condition, but a 25% daily turnover is suggested as a default value. Note that additional turnover may be required for winter operations to minimize freezing. Separate inlet and outlet lines should be provided.

7.0.3. Location

a. The bottom of reservoirs and standpipes and footings for elevated tanks shall be above the 100 year return frequency flood level and shall be above the highest known historic flood elevation. Top of footings for elevated tanks shall be at least one foot above the finished grade.

b. The bottom of reservoirs and standpipes and footings for elevated tanks shall be above the true ground water level.

c. The bottom of reservoirs and standpipes should be placed above the normal ground surface. When the bottom must be placed below ground surface, sewers, drains, standing water and similar sources of contamination must be kept at least 50 feet from the reservoir except that specially constructed gravity sewers may be located no closer than 20 feet from the reservoir. These specially constructed gravity sewers shall be made of water main pipe pressure tested in place to 50 psig pressure without leakage. The top of the reservoirs shall not be less than two feet above the normal ground surface except that clear wells under filters may

be exempted when the total design gives the same protection. The area surrounding a ground level structure shall be graded in a manner that will prevent surface water from standing within 50 feet of it. Steel storage tanks shall not be located below the ground surface.

7.0.4. Roofs on Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures shall have suitable watertight roofs that prevent entrance of birds, animals, insects, and excessive dust. The roof shall be well drained. Downspouts shall not enter or pass through the storage structure.

7.0.5. Protection of Finished Water Storage Structures

All finished water storage structures shall be protected from trespassing, vandalism, and sabotage. Protection shall include at least the following:

a. Locked hatches and other access openings;
b. Physical barriers to entrance of ladders; and
c. Security fencing with locked gates.

See also section 2.5, Security Measures.

7.0.6. Vents on Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures shall be vented. Overflows shall not be considered vents. Open construction between the sidewall and roof is not permissible. Vents shall meet the following criteria:

a. Vents shall be sized with sufficient capacity to pass air so that the maximum flow of water entering or leaving the tank will not cause excessive pressure or vacuum. Maximum flow of water leaving the tank shall include the rate produced by a catastrophic large main failure near the tank. Resistance of air flow caused by the vent screens shall be considered in sizing the vents;
b. Vents shall be designed to exclude precipitation, shall be screened to exclude birds, insects, and animals and shall terminate a minimum of 24 inches above the roof. Eighteen mesh noncorrodible screen may be used. The finished water storage structure shall also be equipped with a pressure-vacuum relief mechanism that will operate should the finer mesh screens be frost plugged or clogged with foreign material. The primary purpose of the vents is to prevent catastrophic structural failure of the tank caused by pressure differential. No modifications shall be made to vents to interfere with this primary purpose; and
c. Clearwell vents shall vent to the outside.

7.0.7. Overflows on Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures shall be provided with an overflow. Overflows shall meet the following criteria:

a. Overflows shall be sized to permit the waste of water in excess of the maximum filling rate with a head not more than six inches above the lip of the overflow. Resistance of flow through the screen or flap shall be considered in sizing the overflow;
b. Overflows shall be brought down to an elevation between 12 and 24 inches above the ground surface, shall terminate at the bottom with an elbow directed away from the foundation, and shall discharge over a drainage inlet structure or splash plate. Overflows shall not be directly connected to a sewer or storm drain;
c. Overflows shall be protected from entrance of birds or animals by a tight fitting counterweighted flap valve. Overflows should be diverted to minimize property damage and inconvenience to adjacent property owners; and
d. Overflows shall be provided for all clearwells.

7.0.8. Freeze Protection for Unpressurized Finished Water Storage Structures

All unpressurized finished water storage structures and their appurtenances including the internal structural components riser pipes, overflows, vents, and hatches shall be designed to prevent freezing that will interfere with proper functioning or cause structural damage to the storage vessel. Design shall be based on a 100 year return frequency extended low temperature period and average wind velocity.

7.0.9. Catwalks

Every catwalk over finished water in a storage structure shall have a solid floor with raised edges so designed that shoe scrapings and dirt will not fall into the water.

7.0.10. Corrosion Protection

Proper protection shall be given to metal surfaces. Tanks constructed of steel, wrought iron, or other metals subjects to corrosion shall have both interior and exterior surfaces painted, except that bottoms of reservoirs and standpipes should not be painted.

a. Exterior paint should contain less than 100 milligrams of lead per kilogram of dried paint to prevent removed paint from being classified as a hazardous waste.
b. Exterior paint color should be chosen to help manage the temperature of stored water to reduce freezing or reduce excessive summer temperatures as needed.
c. Interior paint systems shall be certified for drinking water use under the latest ANSI/NSF Standard 61.
d. Interior paint systems shall be properly applied and cured and shall not transfer any substance to the water that results in a violation of a maximum contaminant level or secondary contaminant level outlined

in 10 CSR 60, Chapter 4. Curing should also be done to eliminate tastes and odors. After painting and proper curing are completed and the tank is filled, the water that exhibits such odors shall be tested for each paint constituent that is listed in 10 CSR 60, Chapter 4 prior to placing the tank in service.

e. Tanks constructed of corrosion resistant metals shall be designed to meet the same structural requirements outlined in section 2.1.1. and shall not be required to be painted. Corrosion resistant metals shall be chosen to resist corrosion from all naturally occurring chemicals in the water stored, all chemicals added as part of water treatment including the addition of chlorine and other disinfectants, and the natural atmosphere including current and expected future air pollutants in the area.

7.0.11. Drains on Unpressurized Tanks and Reservoirs

Unpressurized tanks and reservoirs shall be equipped with a drain and have facilities for collecting bacteriological samples.

a. Elevated tanks and standpipes with a nominal capacity of 30,000 gallons or more that provide pressure by gravity shall be equipped with a fire hydrant with one pumper (steamer) nozzle of approximately 4½ inches in diameter and two hose nozzles of approximately 2½ inches diameter. The piping, valves, and fire hydrant shall be designed and constructed to allow the tank to be taken off line and drained through the fire hydrant.
b. Other above ground tanks shall be equipped with a fire hydrant or flush hydrant. The piping, valves, and hydrant shall be designed and constructed to allow the tank to be taken offline and drained through the flush hydrant or fire hydrant.
c. No drain shall have a direct connection to a sewer or storm drain. The design and construction shall allow tanks and reservoirs to be taken offline, drained, cleaned, repaired, and painted without causing loss of pressure in the distribution system.

7.0.12. Roofs and Sidewalls on Unpressurized Tanks and Reservoirs

Unpressurized tanks and reservoirs shall have roofs and sidewalls designed and constructed to preserve the quality of the water stored.

a. The roof and sidewalls must be water tight with no openings except properly constructed vents, manways, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow.
b. Any pipes running through the roof or sidewall of a finished water storage structure must be welded or properly gasketed in metal tanks. In concrete tanks these pipes shall be connected to standard wall castings. These wall castings should have seepage rings imbedded in the concrete.
c. Openings in a structure roof or top designed to accommodate control apparatus or pump columns shall be curbed and sleeved with proper

additional shielding to prevent the access of surface or floor drainage water into the structure.

d. Valves and controls shall be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir.

7.0.13. Access to Unpressurized Finished Water Storage Structures

Unpressurized finished water storage structures shall be designed and constructed to allow convenient access to the interior for cleaning and maintenance. The number, location, and spacing of hatches and manways shall conform to the federal Occupational Safety and Health Administration (OSHA) regulation 29 CFR, Part 1910. Roof or top hatches shall be framed at least six inches above the surface of the roof or top at the opening, shall be fitted with a solid, water tight, hinged cover which overlaps the framed opening and extends down around the frame at least two inches, and shall have a locking device.

7.0.14. Discharge Pipes

The discharge pipes from all reservoirs shall be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

7.0.15. Safety Devices at Unpressurized Finished Water Storage Structures

Unpressurized tanks and reservoirs shall be equipped with safety devices to allow safe inspection, repairs, maintenance, and painting.

a. Ladders, handrails, safety cages and other safety appurtenances shall conform to the federal OSHA regulation 29 CFR, Part 1910. These safety appurtenances shall also conform to any applicable local ordinances, codes, or standards that are more restrictive than OSHA standards. No wire, cable or other device shall be attached to the ladders, handrails or other safety appurtenances in such a manner that will obstruct or impair the safe use of these devices.
b. Ladders, ladder guards, balcony railings, and safely located entrance hatches shall be provided where applicable.
c. Railings or handholds shall be provided on elevated tanks where persons must transfer from the access tube to the water compartment.
d. Elevated tanks with riser pipes over eight inches in diameter shall have protective bars over the riser opening or a safety handrail around the riser opening inside the tank.
e. Warning lights should be provided on standpipes and elevated storage tanks and shall be provided when required by the Federal Aviation Administration (FAA) or local codes.

f. Cables, power conduits, antenna brackets or similar devices shall be installed inside properly constructed conduits. Properly designed brackets must secure these to the storage structure.

7.0.16. Disinfection of Unpressurized Finished Water Storage Structures

Disinfection of unpressurized finished water storage tanks and reservoirs following construction, repairs, painting, or other maintenance shall be done in accordance with the latest edition of the AWWA Standard for Disinfection of Water-Storage Facilities, AWWA C652.

a. At least one sample shall be analyzed to indicate microbiologically satisfactory water before the facility is placed into operation.
b. Disposal of chlorinated water from the tank shall be in accordance with Missouri Clean Water Commission requirements to protect aquatic life.

7.1. Tanks and Reservoirs for Finished Water Storage

7.1.1. Fire Protection.

Public water supplies that provide fire protection shall have finished water storage tanks, reservoirs, and other facilities with sufficient capacity to provide minimum design needed fire flow for the length of fire duration and shall provide adequate storage to meet diurnal peak flow with fire flow being considered.

a. The minimum allowable design needed fire flow and design supply works capacity are 250 gallons per minute for a fire duration of two hours.
b. Other commonly used design needed fire flows with the equivalent fire durations are listed in section 7.5.

7.1.2. No Fire Protection.

Public water supplies that do not provide the fire protection shall have sufficient finished water storage to meet the minimum design operating pressure and flow for the diurnal flow pattern on the design maximum usage day with all well pumps, treatment plants, high service pumps, booster pumps, or other equipment that affect pressure and flow in operation. This can be achieved by the following methods:

a. Provide finished water elevated storage with nominal capacity equal to or greater than one day's average demand. For standpipes, the volume above the elevation, which provides 20 psig at the tower base, shall be counted as nominal capacity. (This method does not require documentation or estimation of diurnal flow pattern or design maximum day usage.)

b. Provide ground level finished water storage with nominal capacity equal to or greater than one day's average demand. Duplex high service pumps with capacity capable of meeting design instantaneous peak flow with the

largest pump out of service shall be provided with this option. Note the volume above low level withdrawal pump shut down is counted as nominal capacity. (This method does not require documentation or estimation of diurnal flow pattern or design maximum day's usage.)

c. Estimate or document diurnal flow pattern and design maximum day's usage. Calculate the minimum nominal finished water storage needed to maintain design operating pressure and flow with all well pumps, treatment plants high service pumps, booster pumps or other equipment that affect pressure and flow in operation. The minimum storage needed will vary for each public water supply but 25% of design maximum day's usage is a reasonable default value.

d. Provide hydropneumatic storage as outlined in section 7.4.

7.1.3. Tank and Reservoir Capacity for Unpressurized Tanks

Tank and reservoir capacities estimated in engineering design studies and finalized in engineering final plans and as-built plans submitted to the department shall include the elevation and volume data specified here.

7.1.3.1. Elevations.

All of the elevations specified here, expressed to the nearest 0.1 feet above mean sea level (msl), shall be provided for all nonpressurized tanks. For preliminary engineering designs, the msl elevations may be estimated from United States Geological Survey (USGS) 7.5 minute Quadrangle maps but the public water supply, the engineer and the funding agency must recognize that this method of estimating elevations is subject to significant error and corrections of preliminary errors in elevation on elevated tanks may substantially change the cost of the project. For final engineering plans and as-built plans, the msl elevations shall be determined by measurement from a known USGS or department elevation monument.

1. Elevation of the finished grade (ground surface) at the base or under the tank.
2. Elevation of the actual tank bottom.
3. Elevation of the bottom capacity level (point at which the tank normally discharges).
4. Elevation at which the withdrawal pumps shut down because of low level (applicable to tanks/reservoirs with withdrawal pumps).
5. Elevation which will provide twenty pounds per square inch gage (20 psig) static pressure at finished grade at the base of the tank (applicable to standpipes that provide pressure by gravity).
6. Elevation which will provide twenty pounds per square inch gage (20 psig) static pressure at the highest surface elevation in the area to be served by the tank (applicable to standpipes that provide pressure by gravity.

7. Elevation at which the filling pump starts (or the filling control valve opens).
8. Elevation at which the filling pump stops (or filling control valve closes).
9. Elevation at which the tank/reservoir begins to overflow.
10. Elevation at the top of the tank or reservoir (or roof of the tank or reservoir).

7.1.3.2. Volumes.

All of volumes specified here, expressed to the nearest 100 gallons, shall be provided for all unpressurized tanks.

1. Volume between the elevations of the bottom capacity level (point at which the tank normally discharges) and the elevation at which the tank begins to overflow (applicable to elevated tanks). This is the nominal capacity for elevated tanks.
2. Volume between the elevation of the bottom capacity level (point at which the tank normally discharges) and the elevation at which the filling pump starts (or filling control valve opens). This is the available fire suppression volume for elevated tanks.
3. Volume between the elevation that will provide 20 psig static pressure at finished grade at the base of the tank and the elevation at which the tank begins to overflow (applicable to standpipes that provide pressure by gravity). This is the nominal capacity for standpipes.
4. Volume between the elevation that will provide 20 psig static pressure at finished grade at the base of the tank and the elevation at which the filling pump starts (or the filling control valve opens). This is the available fire suppression volume for standpipes.
5. Volume between the elevation at which the withdrawal pumps shut down because of low level and the elevation at which the reservoir begins to overflow (applicable to reservoirs/tanks with withdrawal pumps). This is the nominal capacity for reservoirs.
6. Volume between the elevation at which the withdrawal pumps shut down because of low level and the elevation at which the filling pump starts (or the filling control valve opens). This is the fire suppression volume for reservoirs.
7. Volume between the elevation at which the filling pump starts (or the filling control valve opens) and the elevation at which the filling pump stops (or the filling control valve closes). This is the turnover volume for tanks/reservoirs used to assess filling pump run lengths and heat loss/ice formation calculations.
8. In addition to the above volume information, the engineer shall submit a table or graph as part of the as-built plans that shows tank volume from actual tank bottom to the overflow in increments no greater than one foot elevation change. The basis for this table or graph shall be identified and geometric calculations shown or actual metered volumes listed.

7.1.4. Costs

As part of the final engineering certification on a tank/reservoir construction project, the engineer shall submit the final cost of the tank excluding land or easement costs.

7.2. Plant Storage

These requirements are in addition to the applicable requirements listed in subsections 7.0. and 7.1.

7.2.1. Filter Backwash.

Wash water tanks shall be sized to provide the filter backwash at the design filter backwash rate. The wash water tanks, pumps, and finished water storage must be designed to allow backwashing several filters in rapid succession in order to meet the most extreme plant operational problems expected. Plants with three or fewer filters should have sufficient wash water capacity to backwash all filters in rapid succession.

7.2.2. Clear Wells.

Clear wells shall be designed and constructed as part of the overall design of plant and distribution facilities to provide adequate disinfection, adequate backwash volume, and adequate distribution flow and pressure.

7.2.3.1. A suitable vent(s) and overflow shall be provided.

7.2.3.2. Disinfectant contact time shall meet the requirements of the January 1992 Missouri Department of Natural Resources' Public Drinking Water Program Guidance Manual for Surface Water System Treatment Requirements and 10 CSR 60-4.055 Disinfection Requirements.

7.2.3.3. Clearwell storage should be sized in conjunction with distribution system storage to allow constant rate plant operation without intermittent shutdowns. A minimum of two clear well compartments should be provided.

7.2.3.4. Clearwell storage should be sized to allow the flexibility of one, two, or three eighth-hours shifts per day operation.

7.2.3. Receiving Basins and Pump Wet Wells

Receiving basins and pump wet wells for finished water shall be designed as finished water storage structures.

7.2.4. Finished Water Adjacent to Unsafe Water

Finished water must not be stored or conveyed into a compartment adjacent to unsafe water when the two compartments are separated by a single wall.

7.3. Distribution Storage

These requirements are in addition to the applicable requirements listed in subsections 7.0. and 7.1.

7.3.1. Minimum PSIG at Normal Ground Elevation

Distribution storage shall be designed and constructed in conjunction with production facilities, pumping facilities, and distribution mains to provide a minimum of 35 psig pressure at the normal ground elevation at every point of the distribution system during all conditions of design flow. Normal operating conditions include extended drought usage and diurnal peak flow.

7.3.2. Working Pressure PSIG at Normal Ground Elevation

Distribution storage should be designed and constructed in conjunction with production facilities, pumping facilities, and distribution mains to provide a working pressure of 60 psig at the normal ground elevation at every point in the distribution system during all normal operating conditions except fire flow.

a. Areas with elevation differences of more than 150 feet should be divided into multiple pressure zones so that each zone has pressure between 35 and 100 psig.
b. Multiple pressure zone systems should have separate storage facilities for each zone and should be equipped so that water can be transferred between zones with pump stations and pressure control valves.
c. Each public water system shall be designed to maintain normal system pressures and flows with any storage facility out of service for maintenance or should have at least two storage tanks or reservoirs so that removing a tank or reservoir for maintenance will not disrupt distribution system pressure.

7.3.3. Distribution Storage Controls

Distribution storage facilities shall be equipped with adequate controls to maintain levels in the tanks/reservoirs.

a. Level indicating devices should be located at a central location.
b. Pumps should be controlled from tank levels with the signal transmitted by telemetering equipment when any appreciable head loss occurs in the distribution system between the pump and the storage structure. Pressure control valves (usually installed on the discharge line and pump to waste line with a control system that opens and closes these valves simultaneous to control pressure surge/water hammer) should be installed on pumps when pumps and storage facilities are not adjacent.
c. Overflow and low level warnings or alarms should be located at places in the community where these will be under responsible surveillance 24 hours per day.

7.4. Hydropneumatic Storage

7.4.1. Hydropneumatic storage.

Hydropneumatic storage (pressure tanks or bladder tanks) shall not be used as the only storage facilities for community public water systems serving more than 50 connections.

7.4.2. Pressure tanks.

Pressure tanks shall be designed and operated so that one-third (1/3) of the total volume functions as a permanent water seal.

7.4.3. Boyle's Law.

Boyle's Law shall be used to design the volume of the gas phase of pressure tanks and bladder tanks.

Boyle's Law: $P_1V_1 = P_2V_2$

Where P is absolute pressure and V is volume.

For units of pounds per square inch, absolute pressure is: psia = psig + 14.7

Where psia indicates absolute pressure and psig indicates gage pressure.

For commonly used pressure ranges (pump on to pump off) and 1/3 total volume of pressure tanks used at water seal, the following table based on Boyle's Law may be used for design. Note that usable volume is also called drawdown volume and that bladder tanks have no permanent water seal.

Figure 4 - Hydropneumatic Tank Usable Volume

Tank Type		Pressure Range		
		20-40 psig	30-50 psig	40-60 psig
Pressure	Percent of total volume	42.29%	46.06%	48.82%
	Permanent gas cushion usable volume	24.38%	20.61%	17.85%
	Permanent water seal	33.33%	33.33%	33.33%
Bladder	Permanent gas cushion	63.44%	60.09%	73.23%
	Usable volume	36.56%	30.91%	26.77%

7.4.4 Pressure tanks or bladder tanks used as the only storage for small community water supplies.

Pressure tanks or bladder tanks used as the only storage for small community water supplies shall have a minimum usable volume of 6.25 gallons per person served. (Note this is equivalent to 35 gallons gross volume per person

served when the pressure range is 40 to 60 psig and the water seal is 1/3 of the total volume for a pressure tank.)

7.4.5. Pressure/Bladder Tanks Used with Other Storage and Booster Pumps

Pressure tanks or bladder tanks used in conjunction with other storage and booster pumps and those used as the only storage for noncommunity public water supplies shall have a usable volume sufficient to store at least two minutes' discharge from the largest supplying pump.

7.4.6. Pressure Tanks -- Separate Inlet and Outlet Lines

Pressure tanks shall have separate inlet and outlet lines to provide positive flow through the tanks.

7.4.7. Bladder Tanks - Individually Connected

Bladder tanks shall be individually connected to the supply line to the distribution system to improve circulation to individual tanks.

7.4.8. Certification of Hydropneumatic Tanks

Hydropnuematic tanks shall be certified for drinking water use under the latest version of ANSI/NSF Standard 61.

7.4.9. Hydropneumatic Tank Design and Construction

Hydropneumatic tanks should be designed and constructed in accordance with the latest ASME Boiler and Pressure Vessel Code Section II, Part A, B, C, D, Section V, Section VIII Division I and Section IX published by the American Society of Mechanical Engineers.

7.4.10. Pressure Tanks That Provide Disinfection Contact Time

Pressure tanks that provide disinfection contact time shall be designed to meet requirements of the January 1992 Missouri Department of Natural Resources' Public Drinking Water Program Guidance Manual For Surface Water System Treatment Requirements and 10 CSR 60-4.055 Disinfection Requirements.

7.4.11. Pressure Tanks with Gross Volume of 1,000 Gallons or More

Pressure tanks with gross volume of 1,000 gallons or more per tank shall be designed and constructed with the following appurtenances and features:

a. Each tank shall have at least one manway with minimum diameter 24-inch clear opening for circular manways or 18 inches by 22 inches minimum dimensions for elliptical manways. Additions manways should be

provided on larger tanks as needed for access and ventilation during painting;

b. Each tank shall have a water sight glass, a pressure gage, a mechanical means of adding air, a pressure blow off for excess air, and a drain. The drain shall discharge above the normal ground surface with no direct connection to a sewer or storm drain;
c. The piping connected to each tank shall be equipped with sufficient valves and bypass lines to allow the tank to be taken offline, drained, cleaned, repaired and painted without causing loss of pressure in the distribution system;
d. Each tank shall have adequate automatic controls to manage both the water level in the tank and the pressure of the air cushion; and
e. Each tank shall be sufficiently housed to protect all appurtenances and the tank from freezing. Each tank shall be located above the normal ground surface. Design shall be based on a 100-year return frequency extended low temperature period and average wind velocity.

7.4.12. Pressure and Bladder Tanks with Gross Volume of less than 1,000 Gallons

Pressure tanks and bladder tanks with gross volume less than 1,000 gallons per tank shall be designed and constructed with the following appurtenances and features:

a. Each tank shall be above the normal ground surface and completely housed in a heated building to prevent freezing;
b. The piping connecting tanks shall have sufficient valves and bypass lines to allow each individual tank to be taken offline, drained, repaired, painted, or replaced without causing loss of pressure in the distribution system;
c. The tanks shall be equipped with automatic controls to control pressure/water level in the tanks. A means to manage the volume and pressure of air in the air cushion of pressure tanks shall be provided but this may be done manually with portable equipment. There shall be at least one pressure gage in the tank manifold; and
d. Multiple tanks may be used to achieve the total design volume needed.

7.4.13. Protection to Metal Surfaces

Proper protection shall be given to metal surfaces of pressure tanks

a. Tanks constructed of steel or other metal subject to corrosion shall have both interior and exterior surfaces painted.
    1. Exterior paint should contain less than 100 milligrams of lead per kilogram of dried paint to prevent removed paint from being classified as a hazardous waste.
    2. Interior paint shall be certified for drinking water use under the latest ANSI/NSF Standard 61.
b. Tanks constructed of corrosion resistant metals shall not be required to be painted. Corrosion resistant metals shall be chosen to resist corrosion

from all naturally occurring chemicals in the water stored, all chemicals added as part of water treatment including chlorine and other disinfectants and the natural atmosphere including current and expected future air pollutants in the area.

7.5. Fire Flow Information

7.5.1. Standard Fire Flow with Corresponding Fire Durations.

Standard fire flow with corresponding fire duration is indicated in the table here.

Figure 5 - Design Needed Fire Flow

Design Needed Fire Flow (gallons per minute)	Fire Duration (hours)
250	2
500	2
750	2
1,000	2
1,250	2
1,500	2
1,750	2
2,000	2
2,250	2
2,500	2
3,000	3
3,500	3
4,000	4
4,500	4
5,000	4
5,500	4
6,000	4
6,500	4
7,000	4
7,500	4
8,000	4
8,500	4
9,000	4
9,500	4
10,000	4
11,000	4
12,000	4

7.5.2. Fire Suppression Rating Schedule.

Public water supplies that provide fire protection should determine design needed fire flow and design supply works capacity in accordance with the latest Fire Suppression Rating Schedule published by Insurance Services Organization Inc. (ISO). Ideally, design supply works capacity should equal or exceed design needed fire flow.

7.5.3. Storage for Fire Flow

Storage for fire flow is only one of many components that must be assessed in the engineering design of public water supplies' fire suppression capability. Many other factors not related to water supply, including emergency communications capability, fire department capability, building code requirements, and zoning departments, influence fire suppression capability and ISO rating. All of these factors and local fire district requirements should be assessed in the engineering design for public water supply facilities that will support fire suppression. In general, public water supplies with populations greater than 250 persons and with service connection densities greater than 16 service connections per 160 acres should consider providing at least the levels of fire flow in the Table below.

Figure 6 - Population and Fire Flow

Population	Fire Flow in Residential Areas	Fire Flow in Commercial Areas
250-999	250 gpm for 2 hours	250 gpm for 2 hours
1,000 to 9,999	1000 gpm for 2 hours	2,500 gpm for 2 hours
10,000 and greater	1,500 gpm for 2 hours	3,500 gpm for 3 hours

Chapter 8 - Distribution Systems

8.0. Materials.

8.0.1. Standards and materials selection.

Pipes shall conform to the latest edition of the AWWA, ASTM, Plastic Pipe Institute (PPI), or UniBell Plastic Pipe Association standards or recommendations. Fittings, valves, and fire hydrants shall conform to the latest standards issued by the AWWA and shall be certified by NSF for use in drinking water. Special attention shall be given to selecting pipe materials that will protect against both internal and external pipe corrosion. PVC pipes that are less than three inches in diameter must be at least Class 200 and conform to SDR-21. PVC pipes three inches through 12 inches in diameter shall be no less than Class 160 and conform to SDR-26. Pipes, fittings, and appurtenances containing more than 8 percent lead shall not be used.

8.0.2 Permeation of pipe walls.

In areas that are contaminated with organic chemicals, permeation of organic chemicals into the water system shall be prevented by using non-permeable materials for all portions of the water system including pipe, fittings, service connections, and hydrant leads.

8.0.3. Used materials

Only water mains that been used previously for conveying potable water may be reused, and must meet the above standards and have been practically restored to their original condition.

8.0.4. Joints.

Packing and jointing materials used in the joints of pipe shall conform to the latest edition of the AWWA standards. Pipe having mechanical joints or slip-on joints with rubber gaskets is preferred.

8.1. Water Main Design

8.1.1. Pressure.

All water mains shall be sized in accordance with a hydraulic analysis based on flow demands and pressure requirements. The system shall be designed to maintain a minimum pressure of 35 psi at ground level at all points in the distribution system under all conditions of design flow not including fire flow, except that the department may approve a minimum design pressure of 20 psi

in areas served by rural water districts. The normal working pressure in the distribution system should be approximately 60 psi.

8.1.2. Diameter.

a. The minimum size of a water main for providing fire protection and serving fire hydrants shall be six inches in diameter. Larger mains shall be required, if necessary, to allow withdrawal of the required fire flow while maintaining the minimum residual pressure of 20 pounds per square inch throughout the distribution system.
b. For public water systems not providing fire protection, no main shall be smaller than two inches in diameter.

8.1.3. Fire Protection

When fire protection is to be provided, system design should be such that fire flows and facilities meet the classification criteria of the state Insurance Services Office (ISO). Water mains not designed to carry fire-flows shall not have fire hydrants connected to them.

8.1.4. Flushing.

a. Flushing devices and valving shall be provided to allow every main in the distribution system to be flushed. Flushing devices should be sized to provide flows that will give a velocity of at least 2.5 feet per second in the water main being flushed.
b. In order to provide increased reliability of service and reduce head loss, dead ends shall be minimized by making appropriate tie-ins whenever practical.
c. Where dead-end mains occur, they shall be provided with an approved flushing device.
d. No flushing device shall be directly connected to any sewer.

8.2. Valves.

Sufficient valves shall be provided on water mains so that inconvenience and sanitary hazards to customers will be minimized during repairs. Valves should be located at not more than 500 foot intervals in commercial districts and at not more than one block (or 800 foot) intervals in residential or other districts. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should be at every water main branch on both the feeder main and the branch line.

8.3. Fire Hydrants.

8.3.1. Location and spacing.

Hydrants should be provided at each street intersection and at intermediate points between intersections to meet the classification criteria of the state ISO. Generally, hydrant spacing may range from 350 to 600 feet, depending on the area being served.

8.3.2. Valves and nozzles.

Fire hydrants should have a minimum bottom valve size of at least five inches, one 4-1/2 inch pumper nozzle, and two 2-1/2 inch nozzles.

8.3.3. Hydrant leads.

The hydrant lead shall be a minimum of six inches in diameter and contain a shutoff valve.

8.3.4. Drainage.

A gravel pocket or dry well shall be provided unless the natural soils will provide adequate drainage for the hydrant barrel. Hydrant drains shall not be connected to or located within ten feet of sanitary sewers or storm drains.

8.4. Air Relief Valves; Valve, Meter and Blow-Off Chambers

8.4.1. Location.

At high points in water mains where air can accumulate, provisions shall be made to remove the air by means of manually operated hydrants or automatic air relief valves. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur.

8.4.2. Piping.

The open end of an air relief pipe from automatic valves shall be extended to at least one foot above grade and provided with a screened, downward-facing elbow. The pipe from a manually operated valve shall be capped with a threaded removable cap or plug and should be extended to the top of the pit. Vaults or wells housing automatic air relief valves shall be drained to daylight with drains sized to carry the maximum output of the air relief valve.

8.4.3. Chamber drainage.

Chambers, pits, or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, shall not be connected directly to any storm drain or sanitary sewer, nor shall blow-offs or air relief valves be

connected directly to any sewer. Such chambers or pits shall be drained to the surface of the ground or provided with sump.

8.5. Installation of Mains.

8.5.1. Standards.

Specifications shall incorporate the provisions of the AWWA standards and/or manufacturer's recommended installation procedures.

8.5.2. Bedding.

a. A continuous and uniform bedding shall be provided in the trench for all buried pipe. Backfill material shall be tamped in layers around the pipe, and to a sufficient height above the pipe that the pipe is adequately supported, stabilized, and protected. Rocks and hard objects larger than one inch diameter found in the trench shall be removed for a depth of at least six inches below the bottom of the pipe. Sand or other fine non-acidic granular material should be used for pipe bedding in high traffic areas. As an alternative, a chipper may be used on the trencher to prepare the soil removed from the trench as bedding in high traffic areas.
b. Width of trenches shall be at least four inches larger than the pipe's diameter.

8.5.3. Cover.

All water mains shall be covered with at least 42 inches of earth or other insulation to prevent freezing. Lesser cover depth may be accepted in certain areas as approved by the department.

8.5.4. Blocking.

All tees, bends, plugs, valves, and hydrants shall be provided with reaction blocking, tie rods, or joints designed to prevent movement. Pre-cast concrete blocks should not be used.

8.5.5. Pressure and leakage testing.

All types of installed pipe shall be pressure tested and leakage tested in accordance with the latest edition of AWWA Standard .

8.5.6. Disinfection.

All new, cleaned, or repaired water mains shall be disinfected in accordance with the latest edition of the AWWA Standard. The specifications shall

include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all water mains.

8.6. Separation of Water Mains, Sanitary Sewers and Combined Sewers

8.6.1. General.

The following factors should be considered in providing adequate separation:

a. Materials and type of joints for water and sewer pipes;
b. Soil conditions;
c. Service and branch connections into the water main and sewer line;
d. Compensating variations in the horizontal and vertical separations;
e. Space for repair and alterations of water and sewer pipes; and
f. Off-setting of water mains around manholes.

8.6.2. Parallel installation.

Water mains shall be laid at least ten feet horizontally from any existing or proposed sewer. The distance shall be measured edge to edge. In cases where it is not practical to maintain a ten-foot separation, the department may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the water main closer to a sewer, provided that the water main is laid in a separate trench or on an undisturbed earth shelf located on one side of the sewer and on either case, at such an elevation that the bottom of the water main is at least 18 inches above the top of the sewer. In areas where the recommended separations cannot be obtained, either the waterline or the sewer line shall be constructed of mechanical joint pipe or cased in a continuous casing.

8.6.3. Crossings.

Water mains crossing sewers shall be laid to provide a minimum vertical clear distance of 18 inches between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer. At crossings, the full length of water pipe shall be located so both joints will be as far from the sewer as possible but in no case less than ten feet. Special structural support for the water and sewer pipes may be required. In areas where the recommended separations cannot be obtained either the waterline or the sewerline shall be constructed of mechanical joint pipe or cased in a continuous casing that extends no less than ten feet on both sides of the crossing.

8.6.4. Exception.

Any variance from the specified separation distances in paragraphs 8.6.2.and 8.6.3. must be submitted to the department for approval.

8.6.5. Force mains.

There shall be at least a ten-foot horizontal separation between water mains and sanitary sewer force mains and they shall be in separate trenches. In areas where these separations cannot be obtained, either the waterline or the sewer line shall be cased in a continuous casing.

8.6.6. Sewer manholes.

No waterline shall be located closer than ten feet to any part of a sanitary or combined sewer manhole.

8.6.7. Disposal facilities.

No waterline shall be located closer than 25 feet to any on-site wastewater disposal facility, agricultural waste disposal facility, or landfill.

8.7. Surface Water Crossings.

Surface water crossings, whether over or under water, present special problems. The department should be consulted before final plans are prepared. Positive joints shall be required in waterways and wet weather streams.

8.7.1. Above-water crossings.

The pipe shall be adequately supported and anchored, protected from damage and freezing and accessible for repair or replacement.

8.7.2. Underwater crossings.

a. Flowing streams.
   A minimum cover of four feet shall be provided over the pipe. When crossing water courses are greater than 15 feet in width, the following shall be provided:
   1. The pipe shall be of special construction, having flexible watertight joints**.** Steel or ductile iron ball-joint river pipe shall be used for open cut crossings. Restrained joint pipe may be used for open cut crossings, provided it is encased in a welded steel casing. Restrained joint or fusion weld pipe shall be used for bored crossings.
   2. Valves shall be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves shall be easily accessible and should not be subject to flooding; and the valve closest to the supply source shall be in an accessible location.
   3. Permanent taps shall be provided on each side of the valve within the manhole to allow insertion of a small meter to determine leakage and for sampling purposes**.**
   4. The stream crossing pipe or casing shall extend at least 15 feet

beyond the upper edge of the stream channel on each side of the stream.

b. Intermittent flowing streams.

1. Restrained joint pipe shall be used for all stream crossings;
2. The pipe shall extend at least 15 feet beyond the upper edge of the stream channel on each side of the stream.

8.8. Backflow Prevention.

The water system must be protected from introduction of contaminants by backflow in accordance with 10 CSR 60-11.010 Prevention of Backflow.

8.9. Water Services and Plumbing.

8.9.1. Plumbing.

8.9.1.1. Water services and plumbing shall conform to relevant local or state plumbing codes, or to the National Plumbing Code.

8.9.1.2. Solders and flux containing more than 0.2% lead shall not be used.

8.9.1.3. Plumbing fittings and fixtures not in compliance with standards established in accordance 42 U.S.C. 300g-6(e) shall not be used.

8.9.2. Booster pumps.

See Chapter 6 of this document.

8.10. Service Meters.

Each service connection shall be individually metered.

8.11. Water Loading Stations.

Water loading stations present special problems since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following requirements shall be met in the design of water loading stations.

8.11.1. Backflow.

An appropriate backflow prevention arrangement shall be incorporated in the piping so there is no backflow to the public water supply.

8.11.2. Filling device.

A filling device shall be used so the hose does not extend into the water vessel to prevent contaminants being transferred from a hauling vessel to others subsequently using the station.

8.11.3. Hose length.

Hoses shall be short enough that they do not contact the ground or any constructed platform. Hanging brackets or rope and pulley hoist are acceptable.